SwRI™ 08.02062

DIESEL FUEL EFFECTS ON LOCOMOTIVE EXHAUST EMISSIONS

By

Steven G. Fritz, P.E.

FINAL REPORT

Prepared For

California Air Resources Board
Stationary Source Division - Fuels Section
P.O. Box 2815
Sacramento, CA 95814

October 2000

DIESEL FUEL EFFECTS ON LOCOMOTIVE EXHAUST EMISSIONS

By

Steven G. Fritz, P.E.

FINAL REPORT

SwRI Project No. 08.02062

Prepared For

California Air Resources Board
Stationary Source Division - Fuels Section
P.O. Box 2815
Sacramento, CA 95814

October 2000

Reviewed by:

Terry L. Ullman, Manager
Department of Emissions Research
Automotive Products and Emissions
Research Division

Approved:

Charles T. Hare, Director
Department of Emissions Research
Automotive Products and Emissions
Research Division

FOREWORD

The work covered by this report was performed for the California Air Resources Board, as outlined in SwRI Proposal No. 08-23088C dated August 10, 1998. Locomotive testing was performed between August 1998 and May 1999.

The liaison with the Association of American Railroads (AAR) was Mr. Michael J. Rush, Associate General Counsel of the AAR Law Department. Three EMD model SD70MAC locomotives were provided by the Burlington Northern Santa Fe Railroad (BNSF). Mr. Mark P. Stehly coordinated BNSF's participation in the program. Three GE Model DASH9-44CW locomotives were provided by the Union Pacific Railroad (UP). Mr. Kent D. Carter of UP coordinated UP's participation in the program. A number of people from the Electro-Motive Division of General Motors Corporation (EMD) and the Transportation Systems Division of the General Electric Company (GE) were contacted on several occasions for information and advice related to the operation of their respective locomotives, and their participation and support is greatly appreciated.

This project was performed by the SwRI Department of Emissions Research of the Automotive Products and Emissions Research Division, under the supervision of Mr. Charles T. Hare, Director, and Mr. Terry L. Ullman, Manager. The Project Manager and Principal Investigator for SwRI was Mr. Steven G. Fritz, Principal Engineer. SwRI technical personnel making significant contributions to the project were Mr. Patrick M. Merritt, Senior Research Scientist; Mr. E. Robert Fanick, Senior Research Scientist; Mr. Kenneth B. Jones, Research Technologist; Mr. C. Eddie Grinstead, Research Technologist; Mr. Jeff Mathis, Senior Technician; Mr. Ernest San Miguel, Technician; and Ms. Kathy Jack, Research Assistant, all of the Department of Emissions Research; and Dr. Joe Pan, Manager of the High Resolution Mass Spectrometry Section, and Mr. Mike Dammann, Manager of the Inorganics and Radiochemistry Section, both within the Analytical and Environmental Chemistry Department of the Chemistry and Chemical Engineering Division.

TABLE OF CONTENTS

APPENDICES

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

AAR	Association of American Railroads
ARB	California Air Resources Board
API	American Petroleum Institute
ASTM	American Society for Testing and Materials
BNSF	Burlington Northern Santa Fe Railway
BSFC	brake specific fuel consumption
CFR	Code of Federal Regulations
CO	carbon monoxide
CO_2	carbon dioxide
cSt	centistokes
DFI/GC	direct filter injection, gas chromatography
EMD	Electro-Motive Division of General Motors Corporation
EP	end point
EPA	Environmental Protection Agency
°F	degrees Fahrenheit
f/a	mass fuel to dry air ratio
g	gram
gal	gallon
H_2O	water
HC	hydrocarbons
HFID	heated flame ionization detector
hp	horsepower
hr	hour
IBP	initial boiling point
in	inch
lb	pound
min	minute
NDIR	non-dispersive infrared
NO_x	oxides of nitrogen
O_2	oxygen
OEM	original equipment manufacturer
PAH	polycyclic aromatic hydrocarbons
PHS	Public Health Service
PM	particulate matter
PN	part number
rpm	revolutions per minute
sec	seconds
SOF	soluble organic fraction
SwRI	Southwest Research Institute
TDC	top dead center
UP	Union Pacific Railroad
VOF	volatile organic fraction
wt	weight
%	percent

EXECUTIVE SUMMARY

This project quantified exhaust emissions of two types of locomotive engines using selected diesel fuels. Locomotive exhaust emission and fuel consumption measurements were performed on six late-model locomotives: three 4,000 hp, EMD SD70MAC, and three 4,400 hp, GE DASH9-44CW. All six locomotives were provided by two participating railroads, the Burlington Northern Santa Fe (BNSF), and the Union Pacific (UP). Emission testing was performed between August 1998 and May 1999 at the Southwest Research Institute™ (SwRI) Locomotive Exhaust Emissions Test Center in San Antonio, Texas. This unique facility was established in 1992 in cooperation with the Association of American Railroads (AAR).

This report contains results of regulated and selected unregulated exhaust emission measurements made on six locomotives, each operating on commercially available CARB fuel, Federal on-highway fuel with a sulfur level of 330 ppm (0.033 weight percent), and a high-sulfur (4,760 ppm) nonroad fuel. Due to the fact that the sulfur level of the "high-sulfur" fuel was higher than nonroad diesel fuel typically purchased by the railroads, a fourth fuel was also used in the three GE locomotives, which was a nonroad fuel with a sulfur level of 3,190 ppm (0.32 percent). In this report, this fourth fuel is referred to as the "0.3 percent sulfur" fuel, and is considered to be more representative of high sulfur nonroad diesel fuels used by the railroads.

Table 1 gives the average percent change in the line-haul composite emissions between test fuels for the three EMD locomotives. CARB fuel reduced composite NO_X emissions by an average of 4 percent from levels for on-highway fuel, and by an average of 6 percent from levels for high-sulfur, nonroad fuel. CARB fuel reduced composite PM emissions by an average of 3 percent from levels for on-highway fuel, and by an average of 16 percent from levels for high-sulfur, nonroad fuel. Using on-highway fuel reduced composite PM emissions by 13 percent from levels for high-sulfur, nonroad fuel.

Table 1 also gives the average percent change in the line-haul composite emissions between test fuels for the three GE locomotives. CARB fuel reduced composite NO_X emissions by an average of 3 percent from levels for on-highway fuel, and by an average of 7 percent from levels for high-sulfur, nonroad fuel. These results are very consistent with the NO_X response observed for the EMD locomotives.

TABLE 1. AVERAGE CHANGE IN REGULATED LOCOMOTIVE EXHAUST EMISSIONS BETWEEN TEST FUELS

FUEL CHANGE	Percent change in Average Line-Haul Composite Emissions [a]			
	HC	CO	NO_x	PM
EMD SD70MAC				
CARB vs. On-Hwy	+ 1 %	+ 7 %	- 4 %	- 3 %
CARB vs High Sulfur [b]	+ 3 %	+ 8 %	- 6 %	- 16 %
On-Hwy vs High Sulfur [b]	+ 1 %	+ 1 %	- 3 %	- 13 %
GE DASH9-44CW				
CARB vs On-Hwy	- 4 %	- 1 %	- 3 %	- 3 %
CARB vs High Sulfur [b]	+ 2 %	- 2 %	- 7 %	- 39 %
On-Hwy vs High Sulfur [b]	+ 6 %	- 2 %	- 4 %	- 38 %
CARB vs 0.3% Sulfur [c]	+ 1 %	- 3 %	- 5 %	- 27 %
On-Hwy vs 0.3% Sulfur [c]	+ 4 %	- 2 %	- 2 %	- 25 %

Notes: a - EPA Line-Haul duty cycle weighted emissions.
b - 4,670 ppm sulfur nonroad fuel, EM-2664-F
c - 0.3% Sulfur fuel = 3,190 ppm sulfur, EM-2708-F

Using the 0.3 percent sulfur nonroad fuel as the basis of comparison, CARB fuel reduced composite NO_X emissions for the GE locomotives an average of 5 percent. On-highway fuel reduced composite NO_X emissions by 2 percent compared to levels from the 0.3 percent sulfur, nonroad fuel. Table 1 also shows that switching from the high-sulfur (0.476 percent sulfur) fuel to the 0.3 percent sulfur fuel reduced the average composite NO_X emissions from the GE locomotives by 2 percent.

In the GE locomotives, using CARB fuel reduced the average composite PM emissions by an average of 3 percent compared to on-highway fuel, and by an average of 39 percent compared to high-sulfur, nonroad fuel. Using on-highway fuel, average composite PM emissions were reduced by 38 percent compared to high-sulfur, nonroad fuel. Using the 0.3 percent sulfur nonroad fuel as the basis of comparison, CARB fuel reduced composite PM emissions an average of 27 percent compared to 0.3 percent sulfur, nonroad fuel, and using on-highway fuel reduced composite PM emissions by 25 percent compared to the 0.3 percent sulfur, nonroad fuel.

For the two locomotive models tested, switching from the high-sulfur, nonroad diesel fuel to CARB fuel reduced the average NOx emissions by 6-7 percent, which corresponds to a reduction of about 0.8 g/hp-hr. This NO_X reduction is similar to that observed for on-highway diesel engines. No formal statistical analysis of the data was performed by SwRI, but test results were provided to ARB and the AAR for their analysis.

Sulfate analysis of the PM samples indicated that the PM reduction with CARB fuel was largely attributable to the reduced sulfur content of the fuel, and on a g/hp-hr basis, the PM response was essentially the same for each locomotive model. Figure 1 shows the effect of fuel sulfur content on the PM emissions from the two models of locomotives tested. HC and CO emissions were relatively insensitive to the fuels tested, as were smoke emissions. Regardless, the ARB and AAR statistical analyses of the data should be used for the final determination of statistically significant changes in the emissions between fuels.

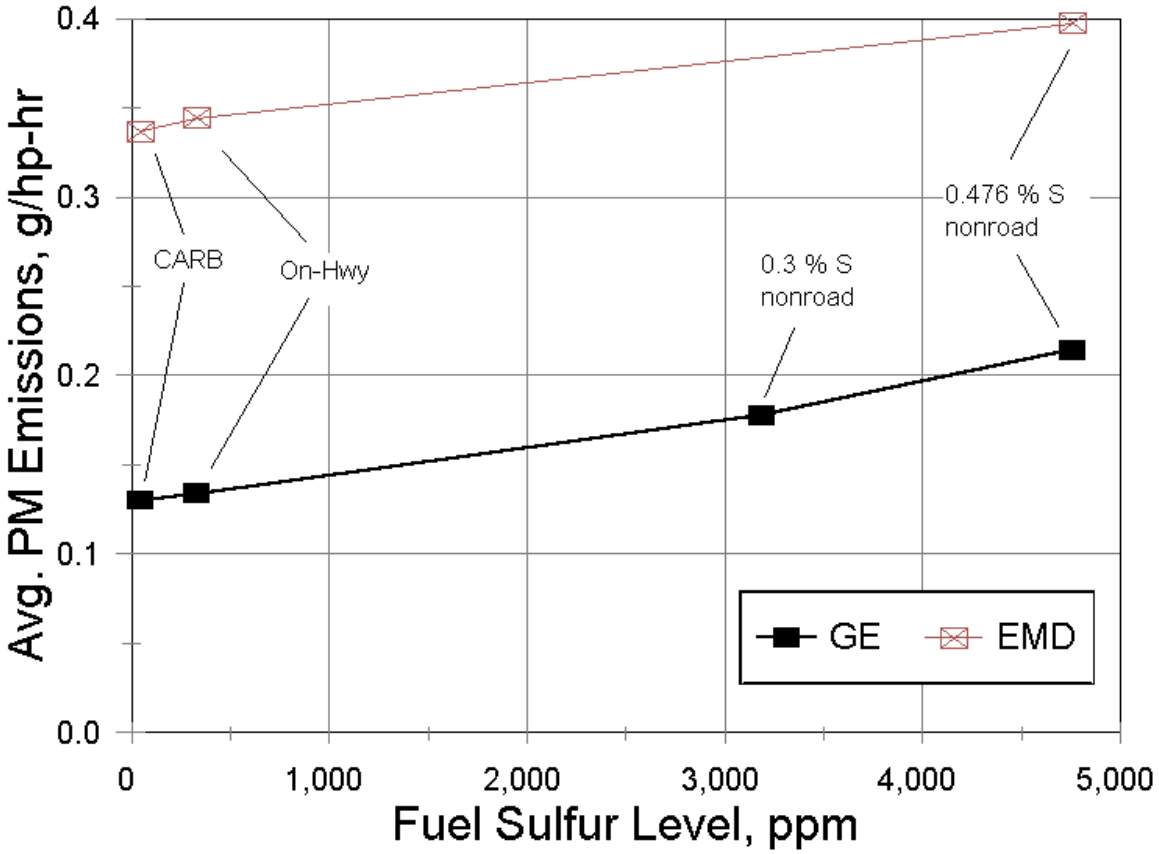

FIGURE 1. EFFECT OF TEST FUEL SULFUR CONTENT ON PM EMISSIONS

I. INTRODUCTION

This project quantified the exhaust emissions from two types of locomotive engines using selected diesel fuels. Locomotive exhaust emission and fuel consumption measurements were performed using three fuels on six locomotives: three high-power, late-model EMD, and three high-power, late-model GE locomotives were tested. A fourth fuel was added after the program began, and was tested in the three GE locomotives. Locomotive selection was the responsibility of the participating railroads, which were the Burlington Northern Santa Fe (BNSF), and the Union Pacific Railroad (UP).

Testing was performed at the Southwest Research Institute (SwRI) Locomotive Exhaust Emissions Test Center in San Antonio, Texas. This unique facility was established in 1992 in cooperation with the Association of American Railroads (AAR), and is the only non-OEM facility capable of performing locomotive exhaust emission tests. To date, over 50 locomotives have been tested by SwRI in work for the AAR, the OEM's, and the U.S. EPA.

A Technical Oversight Committee composed of representatives from ARB, BNSF, UP, and the AAR was formed to provide SwRI with technical direction throughout the project's duration.

II. TECHNICAL APPROACH

Locomotive exhaust emission tests for this project were performed by SwRI at the Locomotive Exhaust Emissions Test Center in San Antonio, Texas. This facility was established in August 1993 in cooperation with the AAR and what was then the Southern Pacific Transportation Company (SP).

Presented below is an overview of the technical approach used to conduct locomotive exhaust emissions testing. Included is a description of the locomotives selected for testing, engine power measurement, fuel consumption measurement, the test fuels used in this program, exhaust emissions test procedures, analytical procedures, particulate measurement procedures, and smoke opacity test procedures.

A. Test Locomotives

Selection of the locomotives for emission testing was the responsibility of the BNSF and UP railroads. The locomotives selected for this study represented current production locomotives covering 1995 and 1996 model years.

Three GE locomotives were provided by UP, and three EMD locomotives were provided by BNSF. Table 2 summarizes the road number, locomotive date of manufacture, locomotive serial number, engine model, and engine serial number for each locomotive.

The line-haul locomotives used in this work were equipped with the "dynamic brake" feature in which the electric motors used for traction can be reverse-excited to become generators to slow the train. The electrical power generated by braking is dissipated in resistance grids contained on the locomotive. The test locomotives, with the self-load feature, were set to dissipate the main alternator power directly into these "dynamic brake" resistance grids, allowing static test of the locomotive.

B. Engine Power Measurement

The goal of “power measurement” is to establish the power produced by the engine, referred to as flywheel or “gross” power, and does not include parasitic power used to support the engine itself, such as fuel pumps, water pumps, etc. The bulk of the engine’s flywheel power is converted to electrical power to drive the traction motors and the

remainder is used for accessory loads. There are subtle differences between the locomotive manufacturers in their approach to quantifying flywheel power. The primary differences arise in alternator efficiencies quoted by the locomotive manufacturers, and approaches in accounting for various accessory loads. Gross power represents the sum of "traction power" plus "auxiliary power". For these tests, observed (uncorrected) gross power was used for computing brake-specific emissions.

TABLE 2. LOCOMOTIVES TESTED

Road Number	Locomotive Date of Manufacture	Locomotive Serial Number	Engine Model	Engine Serial Number
GE Model DASH9-44CW 4,400 hp Locomotives				
UP No. 9715	7/94	47861	7FDL16N54	970309R [a]
UP No. 9724	7/94	47870	7FDL16N62	970815R [b]
UP No. 9733	8/94	47879	7FDL16N7	298951-1
EMD Model SD70MAC 4,000 hp Locomotives				
BNSF No. 9693	11/95	946565-122	16-710G3B-EC	95J1-1033
BNSF No. 9754	4/96	956615-38	16-710G3B-EC	96A1-1030
BNSF No. 9696	12/95	946565-125	16-710G3B-EC	95K1-1004
Notes: a - GE engine 970309R was remanufactured by GE in March 1997. b - GE engine 970815R was remanufactured by GE in August 1997.				

Gross power for the GE locomotives was recorded from the onboard computer display. Recording the gross power using the on-board computer is a deviation from the EPA locomotive test procedure for locomotives, which calls for direct measurement of electrical power with an NIST-traceable accuracy of better than two percent. EPA also requires that the specified alternator efficiency for each test point be given along with the basis for determining the efficiency.[1] Due to the fact that the objective of this study was to document emissions using different fuels on the same locomotive, the absolute accuracy of gross power measurement was of secondary concern, and any small inaccuracies in the measured power would be applied uniformly to emission results for a given locomotive.

[1] CFR, Title 40, Part 92, §92.106 "Equipment for loading the engine."

Like the GE locomotives, the on-board computer display was used to record the traction power from the EMD locomotives. Accessory loads from the auxiliary generator, air compressor, traction motor blower, inertial separator blower, radiator cooling fans, and TCC blower were computed based on published EMD load box test procedures.

Power and fuel rates are reported as observed values. Observed gross power was used to report brake-specific exhaust emissions in g/hp-hr. However, corrected brake-specific fuel consumption (BSFC) values were reported by applying published EMD and GE correction factors for ambient air temperature, barometric pressure, fuel heating value, fuel temperature, and fuel specific gravity.

C. Fuel Consumption Measurement

Diesel fuel consumption rate was measured on a mass basis, using a mass flow meter adapted from laboratory use at SwRI. The system was equipped with a heat exchanger to control fuel supply temperature to 90±10°F. Hot return fuel that normally returns to the locomotive's on-board fuel tank was cooled before returning to the fuel measurement reservoir ("day" tank) to assure consistent fuel supply temperature to the engine.

D. Test Fuels

Four fuels were included in this study, and selected properties of the fuels are summarized in Table 3. Sixteen thousand gallons of "CARB" fuel was provided by Equilon (under separate agreement between CARB and Equilon), and stored on site in a rail tank car provided by BNSF. The CARB fuel was a blend of 8,000 gallons of commercially available CARB-approved fuel from the Texaco refinery in Los Angeles, California, plus another 8,000 gallons of commercially-available CARB-approved fuel from the ARCO refinery in South Gate, California. Both fuels were delivered to the SwRI Locomotive Test Center by truck, and the fuels were mixed in a single tank car. The properties of the CARB fuel were considered by ARB to be representative of commercially available on-highway fuel sold in California.

Federal "on-highway" fuel was a commercially available product purchased by Equilon from Sun Coast Resources, Inc. in Houston, Texas. Sixteen thousand gallons of this fuel were stored on site in a second rail tank car provided by BNSF.

"High-sulfur, nonroad" fuel was also provided by Equilon, and was purchased from the Costal Refining and Marketing, Inc. refinery in Corpus Christi, Texas. This too was a commercially available product. Sixteen thousand gallons of this fuel was stored in a third rail tank car, which was provided by UP. This fuel had a relatively high sulfur content of 4,760 ppm (0.476 weight percent).

Locomotive testing began in September 1998 with three fuels (CARB fuel, on-highway fuel, and high-sulfur, nonroad fuel). Two EMD model SD70MAC locomotives were tested with these three fuels. By the time testing of the first GE locomotive was scheduled, the railroads expressed concern over the unusually high sulfur content (4,760 ppm) of the high-sulfur, nonroad fuel (SwRI fuel code EM-2664-F).

The railroad's position was that this sulfur level was not representative of railroad fuel, and that a fuel sulfur level of approximately 3,000 ppm was more appropriate. A fuel sulfur content of 3,000 ppm would be the mid-point of the range EPA specified, 2,000 ppm to 4,000 ppm sulfur content, for certification testing.[2] In response to the railroad concerns, ARB requested that SwRI blend a fourth test fuel with a target sulfur level of 3,000 ppm.

The approach taken by SwRI was to blend 5,000 gallons of the existing 4,760 ppm sulfur fuel with 3,300 gallons of a blend fuel purchased from Specified Fuels & Chemicals. The blend fuel was selected such that except for sulfur, the remaining fuel properties were similar to the 4,760 ppm sulfur fuel. The fourth test fuel was blended in a fourth tank car that SwRI had available at the test site.

An analysis of the fourth test fuel was performed, and the results are included in Table 3 (SwRI fuel code EM-2708-F), along with the properties of the original three test fuels. The fuel sulfur content of the fourth fuel, the "0.3 percent sulfur nonroad fuel" was 3,190 ppm. Table 3 also shows the specifications for locomotive emissions test fuel given in the Code of Federal Regulations, Title 40, Section 92.113. Although it was not the objective of this program to include a fuel meeting EPA specifications, the 0.3 percent sulfur nonroad fuel met the EPA requirements.

Triplicate emission tests using the fourth fuel were initiated with the first GE locomotive, UP No. 9715, and this fuel was used in addition to the other three fuels. Therefore, a total of twelve tests (triplicate tests on four fuels) were run on UP No. 9715.

[2] 40 CFR, §92.113 "Fuel Specifications".

Adding the fourth test fuel added two test days to the schedule for each of the three GE locomotives. Due to budget constraints, ARB dropped unregulated emissions measurement when using the fourth fuel, and when the third EMD locomotive was tested later in the project, only the three original fuels were used, because it was desired to be consistent with the first two EMD locomotives, tested with only the three original fuels.

TABLE 3. PROPERTIES OF DIESEL FUELS USED IN LOCOMOTIVE TESTING

Determinations	ASTM Test Method	CARB Fuel EM-2663-F	On-Highway Fuel EM-2677-F	High Sulfur Nonroad EM-2664-F	0.3% Sulfur Nonroad EM-2708-F	EPA Locomotive Spec. [a]
API Gravity @ 60EF	D4052	39.1	36.9	33.8	34.1	32 - 37
specific gravity		0.8295	0.8403	0.8561	0.8547	ns
density (lb/gal)		6.92	7.01	7.14	7.13	ns
Viscosity @ 40EC (cSt)	D445-83	2.46	2.29	3.19	2.77	2.0 - 3.2
Sulfur (Wt%)	D2622-94	0.005	0.033	0.476	0.319	0.2 - 0.4
Cetane Index	D976	52.0	47.8	48.6	46.5	40 - 48
Cetane Index	D4737	53.1	47.9	47.8	46.6	ns
Cetane Number	D613-84	51.0	48.9	47.0	44.5	40 - 48
Nitrogen Content (ppm)	D4629-96	8.4	114.4	352.1	220.1	ns
Heat of Combustion	D240					
Gross (BTU/lb)		19,715	19,555	19,457	19,440	ns
Net (BTU/lb)		18,479	18,358	18,270	18,240	ns
Gross (BTU/gal)		136,400	137,100	138,900	138,600	ns
Net (btu/gal)		127,900	128,700	130,400	130,100	ns
Carbon-Hydrogen Ratio	D3178					
% Carbon		86.37	86.88	86.96	86.77	ns
% Hydrogen		13.63	13.12	13.04	13.23	ns
Hydrogen/Carbon Ratio		1.880	1.799	1.788	1.818	ns
SFC Aromatics	D5186-96					
Total Mass %		22.39	30.08	29.50	33.11	27 min.
Total Volume Percent [b]		21.84	28.88	28.35	31.66	
PNA Mass %		1.66	7.83	6.72	8.89	
Hydrocarbon Type	D1319-84					
Aromatics (%)		22.4	32.2	34.4	39.8	ns
Olefins (%)		2.0	3.0	2.6	2.5	ns
Saturates (%)		75.6	64.8	63.0	57.7	ns
Flash Point (EF)	D93-80	167	143	163	166	130 min.
Distillation	D86-96					
	% Recovered	Temp. EF	Temp. EF	Temp. EF	Temp. EF	Temp. EF
	IBP	368	332	360	375	340 - 400
	10	413	391	422	426	400 - 460
	50	490	485	536	513	470 - 540
	90	606	598	638	620	560 - 630
	EP	659	652	682	672	610 - 690

Note: a - Diesel fuel for locomotive testing as specified by EPA in 40 CFR 92, §92.113, Table B113-1.
b - Aromatic hydrocarbons expressed in percent volume = 0.916 x (aromatic hydrocarbons expressed in percent weight) + 1.33, per California Code of Regulations, Title 13, §2282 (c)(1).
ns - not specified

Included with the unregulated emissions analysis planned for this program were measurements for trace quantities of metals within the exhaust particulate. Therefore, an ASTM D-5185 metals analysis of the test fuels was performed to quantify trace quantities of metals that may have been present in the test fuels. The metals of interest were provided by ARB, and these were the same metals of interest for selected exhaust PM samples. ASTM D-5185 essentially outlines a procedure that uses an inductively coupled plasma (ICP) technique for lubricating oil metals analysis. However, for this work, the procedure was applied to diesel fuels.

Table 4 shows that the only metal detected in the test fuels was trace quantities of lead, which was present in both the on-highway fuel and the 0.3 percent sulfur nonroad fuel, in levels just above the detection level of 1 ppm. Other values given in Table 4 indicate that levels of these metals were below the detection limit. The detection limits given were established with readily available calibration standards. Although chloride was included for PM analysis, the ICP technique used to analyze the fuel could not be used for chloride.

TABLE 4. METAL CONTENT OF TEST FUELS

Element	**CARB Fuel** EM-2663-F	**On-Highway Fuel** EM-2677-F	**High Sulfur Nonroad** EM-2664-F	**0.3% Sulfur Nonroad** EM-2708-F
Sb - Antimony	< 1 ppm	< 1 ppm	< 1 ppm	< 1 ppm
As - Arsenic	< 5 ppm	< 5 ppm	< 5 ppm	< 5 ppm
Be - Beryllium	< 2.5 ppm	< 2.5 ppm	< 2.5 ppm	< 5 ppm
Cd - Cadmium	< 1 ppm	< 1 ppm	< 1 ppm	< 1 ppm
Cr - Chromium	< 1 ppm	< 1 ppm	< 1 ppm	< 1 ppm
Co - Cobalt	< 2.5 ppm	< 2.5 ppm	< 2.5 ppm	< 5 ppm
Cu - Copper	< 1 ppm	< 1 ppm	< 1 ppm	< 1 ppm
Pb - Lead	< 1 ppm	**1.1 ppm**	< 1 ppm	**1.0 ppm**
Mn - Manganese	< 1 ppm	< 1 ppm	< 1 ppm	< 1 ppm
Hg - Mercury	< 5 ppm	< 5 ppm	< 5 ppm	< 5 ppm
Ni - Nickel	< 1 ppm	< 1 ppm	< 1 ppm	< 1 ppm
Se - Selenium	< 5 ppm	< 5 ppm	< 5 ppm	< 5 ppm

Note: ASTM D-5185

E. Regulated Exhaust Emissions Test Procedures

SwRI used the Federal Test Procedure (FTP) for locomotives as detailed in Title 40 of the U.S. Code of Federal Regulations (CFR), Part 92, Subpart B, to measure the regulated emissions of hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen (NO_X), particulate matter (PM), and smoke opacity. Deviations from the FTP included using test fuels that did not meet EPA specifications, and using the locomotive's on-board computer display for gross power instead of directly measuring the main alternator voltage and current, as was described earlier in Section II.B of this report.

SwRI ran triplicate FTP tests for emissions on each locomotive for each of the fuels selected. The order of fuels tested was randomized. In accordance with the FTP, emissions of HC, CO, NO_X, and PM were measured for each throttle notch, along with smoke opacity. In addition, switch cycle and line-haul weighted composite emission levels were calculated.

1. Test Modes and Repeat Testing

Following the FTP, SwRI measured steady-state emissions (HC, CO, NO_x, and particulate), smoke opacity, fuel consumption, and power at each throttle notch, starting at idle. Brake-specific emissions were computed for each throttle notch, along with duty-cycle weighted composite emissions.

2. Gaseous Emissions Sampling

The gaseous sample probe was designed using specifications in 40 CFR §86.310-79. Gaseous emissions were sampled directly from within the exhaust stack extension installed on the roof of the locomotive. A heated line was used to transfer the raw exhaust sample to the emission instruments for analysis. Measured gaseous emissions included HC, CO, carbon dioxide (CO_2), oxygen (O_2), and NO_X.

HC concentrations in the raw exhaust were determined using a Rosemount Analytical model 402 heated flame ionization detector (HFID), calibrated on propane. Following diesel emission measurement protocols in the FTP, steady-state NO_X concentration in the raw exhaust was measured with a chemiluminescent instrument. NO_X correction factors for engine intake air temperature and humidity were applied as specified

by EPA in the FTP. Concentrations of CO and CO_2 in the raw exhaust were determined by non-dispersive infrared (NDIR) instruments.

NO_X Correction Factors

The EPA NO_X correction factor given in Title 40 of the Code of Federal Regulations §92.132(d) is:

$$KNO_X = (K) \times (1 + (0.25 \times (\log K)^2)^{1/2}) \quad \textbf{(Eq. 1)}$$

KNO_X is intended to be the total correction applied to the observed NO_X mass emission rate. The "K" term is comprised of two factors, a factor for ambient air humidity correction (K_H), and a factor for ambient air temperature correction (K_T).

$$K = (K_H) \times (K_T) \quad \textbf{(Eq. 2)}$$

From an engineering standpoint, the K_H and K_T terms in Equation No. 2 represent the corrections for humidity and temperature that were based on available data at the time the locomotive rule was published in April 1998.

The ambient air temperature correction factor, K_T, was included in the Locomotive Rule to prevent certificate applicants from deliberately running certification tests at ambient temperatures well below 86°F in an effort to achieve lower NO_X levels. The minimum ambient air temperature allowed is 45°F. On days cooler than 86°F, it is expected that roots-blown EMD engines and new locomotives equipped with separate-circuit charge air cooling would have lower observed NO_X levels than locomotives that use jacket water charge-air cooling systems. The latter are less sensitive to the effects of ambient air temperature within the range of interest (45°F to 105°F).

Ideally, the K_T factor would correct the observed NO_X level to a level expected with an ambient air temperature of 86°F. However, for ambient air temperatures at or above 86°F, the Locomotive Rule fixes $K_T = 1.0$, specifying that no temperature correction is allowed. For ambient air temperatures below 86°F, the value of K_T is adjusted in proportion to the difference between the intake manifold air temperature observed during the test and that observed when ambient temperature was actually 86°F, for the same notch position. Unfortunately, EMD and GE have not published data for the intake manifold air temperature for an 86°F ambient for each throttle notch. In addition, most of the ARB

locomotive tests were run at ambient air temperatures greater than 86°F, so no K_T correction is applicable for those tests, per the Locomotive Rule. Therefore, in the absence of available data from the manufacturers, K_T was set to 1.0 for all test data reported in the ARB fuel-effects study. If manufacturer's data becomes available at a later date, the affected locomotive test data could be reprocessed to include the K_T correction.

Ambient air humidity levels significantly affect NO_X levels from diesel engines. The humidity portion of the NO_X correction factor, K_H, as outlined in §92.132(d), was used in this study.

3. Particulate Emissions Sampling

Particulate emissions were measured at each test point using a "split then dilute" technique, in which a portion of the raw locomotive exhaust was “split” off of the total flow and mixed with filtered air in an 10-inch diameter dilution tunnel. The split sample was transferred to the dilution tunnel through a 2-inch diameter stainless steel tube that was insulated and electrically heated to 375°F. The dilution tunnel was located at ground level, next to the locomotive, as shown in Figure 2.

FIGURE 2. PARTICULATE DILUTION TUNNEL

The dilute exhaust stream in the dilution tunnel was then sampled using probes shown in Figure 3. Particulate was accumulated on 90 mm Pallflex T60A20 fluorocarbon-coated glass fiber filters at a target filter face velocity of 70 cm/s. The filters were mounted in stainless steel filter holders and connected to the dilution tunnel. Sampling time for particulate measurement was typically five minutes. However, this sample time was shortened when observed pressure differential across the filter sets increased beyond a predetermined value of 40 inches H_2O. Particulate filters were preconditioned and weighed before and after test following EPA procedures in the FTP. The particulate mass emission rate was computed using the increase of mass on the filters, the volume of dilute exhaust drawn through the filters, and dilution air and raw exhaust flow parameters.

FIGURE 3. PARTICULATE SAMPLE PROBES LOCATED WITHIN DILUTION TUNNEL

4. Smoke Opacity Test Procedures

Smoke opacity was measured using a modified U.S. Public Health Service (PHS) full-flow opacity meter (smokemeter) mounted above the locomotive exhaust stack. This smokemeter used standard PHS smokemeter optics and electronics, but was modified to a 40-inch diameter to accommodate large exhaust plume diameters. The construction,

calibration, and operation of the smokemeter followed protocols established by EPA for certification testing of locomotive engines as given in the FTP.

Figure 4 shows the smokemeter assembly installed above the exhaust stack extension of a locomotive. The smokemeter was aligned with the long axis of the rectangular exhaust stack. The through-exhaust path length for the single-stack turbocharged locomotives was approximately 37 inches (as determined by the dimensions of the exhaust stack extension). The center of the light beam was positioned 5±1 inches above the outlet of the exhaust stack extension.

FIGURE 4. SwRI SMOKEMETER INSTALLED ON A LOCOMOTIVE

5. Locomotive Test Sequence

Upon delivery of the locomotive to the test site in San Antonio, a self load test was performed to ensure that the locomotive was producing the expected power. The test fuel supply, exhaust stack extension, and smokemeter ring were then installed. A quick test at each of the throttle notches was performed to determine the appropriate instrument ranges to use for each notch.

The test sequence used for locomotive testing is specified in the FTP. Before emission testing was started, the engine was brought to operating temperature. Generally, this involved operating the locomotive at Notch 8 for at least 15 minutes. After the warm-up period, testing began with idle. The FTP calls for a single test point representing dynamic brake (DB) operation. Like the definition of "idle," there may be several options for defining a single DB test point for emission measurements. For this program, tests were performed at the dynamic brake engine operating condition, DB-2.

F. Unregulated Exhaust Emission Test Procedures

Selected unregulated emissions were measured at all throttle notches for selected locomotives and fuels. The ARB requested that the following unregulated emissions be measured:

- Benzene
- 1,3-Butadiene
- Formaldehyde
- Acetaldehyde
- Acrolein
- Polycyclic aromatic hydrocarbons (PAH) (both gas phase and PM phase)
- Volatile Organic Fraction of total particulate (VOF)
- Metal Particulate
- Sulfates
- Soluble organic fraction (SOF) of particulate

Presented below is a brief discussion of the analytical methods used for sampling and analyzing the unregulated emissions.

1. Benzene and 1,3-butadiene - Analyses of benzene in the dilute exhaust was made using a Hewlett-Packard 6890 gas chromatograph (GC), and a flame-ionization detector (FID). The GC was set up at the locomotive test site to facilitate rapid analysis. The analytical setup included a 2 meter pre-column of 0.25 mm I.D. deactivated fused silica, followed by a capillary analytical column (DB-5®, 30 m x 0.25 mm, 0.25 Fm film thickness). The dilute sample was injected via a 5 mL gas sample loop which was maintained at 120EC. The column oven temperature profile began at -80EC and progressed to 250EC.

A Perkin-Elmer model 3920B GC with a FID was set up at the locomotive test center for analysis of 1,3-butadiene. It is important to analyze dilute exhaust samples quickly as butadiene is a reactive species, and the sample concentration can decrease within hours. This GC employed a nine-foot by 1/8-inch stainless steel column packed with 80/100 Carbopak C® coated with 0.19 percent picric acid. The carrier gas was helium, at a flow rate of 27 mL per minute. The column was maintained at 40°C for the entire analysis.

2. Formaldehyde, acetaldehyde and acrolein - To collect aldehydes and ketones, samples of the diluted exhaust and background air were passed through traps containing silica impregnated with 2,4-dinitro-phenylhydrazine (DNPH). Any aldehyde or ketone present in the sampled gas reacted quickly with the DNPH to form a stable derivative. These derivatives were subsequently extracted from the trap by elution with ultra-pure acetonitrile. Analysis of the samples was performed using a high performance liquid chromatograph (HPLC) with ultra-violet (UV) detection.

3. PAH - Gas-phase polycyclic aromatic hydrocarbons (PAH) were collected using PUF/XAD traps. Particulate-phase PAHs were collected using a second pair of 90mm filters that were taken simultaneously with the first set of 90mm PM filters, used to establish PM mass emissions. Target analytes are given in Table 5. The PAH detection limit was approximately 5 ng PAH/sample, assuming no significant amount of interference was present in sample extract after cleanup.

Table 5 also lists the PAH compounds on EPA's "211b" target list. The "211b" list comes from EPA's gasoline and diesel motor vehicle fuel additives registration regulations, detailed in Title 40 CFR, Part 79.

The particulate-laden filters were spiked with a mixture of surrogate solution which contained the deuterated compounds fluorene-d10 and terphenyl-d14, at a final concentration of 1.0 ng/Fl. They were then Soxhlet extracted for 18 hours using a solvent system that contained ethanol (30 percent) and toluene (70 percent). The extracts were blown down and exchanged into hexane. A cleanup procedure was applied which consisted of sulfuric acid wash and gravity chromatography. A cleanup standard of anthracene-d10 at 1.0 ng/Fl was added to monitor the cleanup procedure. The column of the chromatograph was packed with silica gel impregnated with sulfuric acid. The PAHs were eluted out of the column with a solvent system that contained 60 percent dichloromethane (DCM) and 40 percent hexane. The cleaned up extracts were then blown down to 100 µL. A mixture of recovery standards was spiked to the final extracts prior to GC/MS selected ion monitoring analysis. The recovery standards included acenaphthene-d10, pyrene-d10, and benzo(e)pyrene-d12 at a final concentration of 1.0 ng/Fl on column.

The PUF/XAD-2 (gas-phase PAH) traps were extracted, cleaned up, and analyzed the same way as the filters, except that the extraction solvent was DCM. In addition to the recovery standards, a mixture of fifteen deuterated internal standards was added at the time of extraction, to result in a final concentration of 1.0 ng/FL on column. Finally, a matrix

of spike samples and duplicates was analyzed in which all target compounds were spiked at a final concentration of 1.0 ng/FL on column.

TABLE 5. PAH TARGET COMPOUND LIST

PAH Compound	CARB Locomotive Study	EPA 211b Target List
Naphthalene	X	
2-Methylnapthalene	X	
Acenapthene	X	
Acenapthylene	X	
Fluorene	X	
Phenanthrene	X	
Pyrene	X	
Benzo(a)anthracene	X	X
Chrysene	X	X
Benzo(b)fluoranthene	X	X
Benzo(k)fluoranthene	X	X
Benzo(e)pyrene	X	
Benzo(a)pyrene	X	X
Perylene	X	
Indeno(1,2,3-cd)pyrene	X	X
Dibenz(a,h)anthracene	X	X
Benz(g,h,i)perylene	X	X

4. Volatile Organic Fraction of Total Particulate (VOF) - Direct filter injection gas chromatography (DFI/GC) was used to measure the volatile organic fraction (VOF) of diesel particulate emissions using the same 90mm Pallflex T60A20 filter collection media used for particulate mass determination. The contribution of unburned lubricating oil to VOF was determined by an interpretive procedure based on comparison of simulated distillation boiling point distribution of a fresh lubricating oil sample to that of the volatile organic fraction for the total particulate. Therefore, an external standard of locomotive

engine lubricating oil was used to quantify the lubricating oil contribution to the VOF. A major advantage of the DFI/GC method over other methods is that a solvent extraction procedure, which has inherent handling errors, is not required.

Analysis by DFI/GC used a Perkin Elmer Model 8500 gas chromatograph (GC) equipped with a uniquely designed filter injection system and a flame ionization detector (FID). Folded filters were placed into the injector, which was subsequently inserted into a cool zone of the GC to allow any oxygen in the system to be purged without losing any sample by desorption. When all oxygen had been purged from the system, the injector was pushed into a heated zone of the GC inlet, where the volatile materials were desorbed and deposited onto the cool column. The GC temperature program then separated the volatilized compounds by boiling point. These compounds were then detected with an FID.

5. Metal Particulate - 90mm Nucleopore filters were analyzed to determine the weight fraction of metals present in the total PM. This information was then used to compute the mass emission rate of metals in the exhaust. Sample preparation was conducted as follows: each particulate-laden filter was cut in half and placed in a pre-cleaned, Teflon PFA microwave digestion vessel. Ten milliliters of trace metals grade concentrated nitric acid was added to each vessel. The vessel was capped and placed in a CEM MARS5 Microwave Accelerated Reaction System. "Filter XP1500" was the microwave method that was employed. In this method, a power of 1200W was applied to ramp the temperature of the vessel contents to 240EC in 10 minutes; and then it was held at that temperature for an additional 10 minutes. Once the vessels cooled, the samples were transferred to centrifuge tubes and brought up to a final volume of 50 milliliters with deionized water. The digests of the samples were then analyzed for metals using inductively coupled plasma atomic emission spectrometry (ICP-AES) for all elements except mercury, which was run using cold vapor atomic adsorption (CVAA).

6. Sulfates - To isolate the specific effect of fuel sulfur content on PM, sulfate analysis was performed. SO_3 in the dilute engine exhaust reacts rapidly with water in the exhaust to form sulfuric acid aerosols. The aerosols grow to a filterable size range and are collected as a particulate on the PM filters, along with sulfate salts.

The sulfate portion of the total particulate mass accumulated on 90 mm Pallflex T60A20 filter media was quantified using ion chromatography. Any sulfuric acid on the filter was converted to ammonium sulfate by exposure to ammonia vapor in a conditioning chamber. The soluble sulfates were then leached from the filter with a measured volume

of 60 percent isopropanol (IPA) and 40 percent water solution. An aliquot of this extract was injected via autosampler into an ion chromatograph. Anions were separated by the analytical column, and passed through a conductivity detector. The retention time on column provided identification of the anion and the intensity of the signal corresponded to the concentration detected.

The range of the method is quite broad. The instrument is capable of detecting sulfate at levels lower than 0.02 Fg/mL and up to approximately 8 Fg/mL. The sensitivity of this method, however, is limited by the background level of sulfate contained in the Pallflex T60A20 filter media, which is on the order of 0.2 Fg/mL. The values measured for the samples must have the filter background value subtracted. Thus, low sulfate levels in the exhaust may be obscured by correcting for background sulfate present in the filter media. The precision (expressed as coefficient of variation) of the method on the 10 micro siemen scale (which is typically used) with nine observations of a 0.6 Fg/mL standard, is 4.3 percent.

Assuming a detection limit of 0.2 µg/mL in solution, back-calculating for the conditions used for locomotive testing (different power settings), the range of detection limit for this test work is shown in Table 6.

TABLE 6. REPRESENTATIVE DETECTION LIMIT RANGES FOR SULFATE

REPRESENTATIVE DETECTION LIMIT RANGES FOR SULFATE		
mg/hr	mg/bhp-hr	mg/lb fuel
37 - 330	0.1 - 3.5	0.2 - 1.5

7. Soluble Organic Fraction

The soluble portion of the organic fraction of total particulate (SOF) was determined by extracting a portion of the particulate-laden 90 mm Pallflex T60A20 PM filter, using a micro-soxhlet apparatus in accordance with ARB's "Test Method for Soluble Organic Fraction (SOF) Extraction" dated April 1989. Resulting SOF levels were determined using a filter weight loss method. The only variation from the ARB procedure was that the extraction was performed on a 40 percent "pie slice" of the 90 mm PM filter, while the ARB

procedure calls for using a 47 mm diameter filter, and extracting the whole filter. This variation should not adversely affect the SOF results.

III. REGULATED EMISSION TEST RESULTS

A. **EMD** - Table 7 gives average EPA line-haul duty cycle weighted, or composite, emissions of HC, CO, NO_X, and PM for triplicate tests for the three EMD locomotives tested. Individual test summaries for each of the three EMD locomotives are given in Appendices A through C.

TABLE 7. EMD SD70MAC EMISSIONS SUMMARY

Locomotive / Fuel	Average EPA Line-Haul Composite Emissions [a], g/hp-hr			
	HC	CO	NO_X	PM
BNSF No. 9693				
CARB fuel	0.33	2.8	10.8	0.43
On-Highway fuel	0.33	2.6	11.2	0.42
Nonroad High Sulfur fuel	0.32	2.4	11.6	0.50
BNSF No. 9754				
CARB fuel	0.32	2.0	11.6	0.36
On-Highway fuel	0.30	1.8	12.1	0.35
Nonroad High Sulfur fuel	0.32	1.9	12.2	0.40
BNSF No. 9696				
CARB fuel	0.33	1.1	11.3	0.23
On-Highway fuel	0.34	1.1	11.9	0.26
Nonroad High Sulfur fuel	0.32	1.1	12.2	0.29
Notes: a - Average of three tests on each fuel.				

On a given fuel, all three EMD locomotives had similar composite NO_X and HC levels, but the CO and PM levels were not consistent between locomotives. The CO and PM levels measured for BNSF No. 9696 were similar to levels for earlier tests performed by SwRI for the EPA in 1995 on BN No. 9457, which was also an EMD SD70MAC.[3] Results from BNSF No. 9696 show that line-haul composite NO_X and HC emissions are

[3] Fritz, S. G., "Emissions Measurements - Locomotives," SwRI Final Report No. 5374-024, EPA Work Assignments 1-4 and 2-4, Contract No. 68-C2-0144 (August 1995).

consistent with the first two locomotives, but CO and PM levels were much lower, on the order of half the level measured on the first two locomotives. Note that each of the three EMD locomotives tested in this work had new fuel injectors installed prior to testing at SwRI.

Table 8 gives the average percent change in the line-haul composite emissions between test fuels. For the three EMD locomotives, CARB fuel reduced composite NO_X emissions by an average of 4 percent from levels for on-highway fuel, and by an average of 6 percent from levels for high-sulfur, nonroad fuel. SwRI did not perform a formal statistical analysis of the emissions results, because test results were provided to ARB and the AAR for their own statistical analyses.

Table 7 shows that although the average level of composite PM emissions varied considerably between the three EMD locomotives on a given fuel, the PM responses to fuel changes were comparatively consistent. As reported in Table 8, CARB fuel reduced composite PM emissions by an average of 3 percent from levels for on-highway fuel, and by an average of 16 percent from levels for high-sulfur, nonroad fuel. Using on-highway fuel reduced composite PM emissions by 13 percent from levels for high-sulfur, nonroad fuel. The role of fuel sulfur in PM emissions is discussed in Section II.F.6 of this report.

TABLE 8. AVERAGE CHANGE IN REGULATED EMD LOCOMOTIVE EXHAUST EMISSIONS BETWEEN LOCOMOTIVE TEST FUELS

FUEL CHANGE	Percent change in Average EMD Line-Haul Composite Emissions [a]			
	HC	CO	NO_x	PM
CARB vs. On-Hwy	+ 1 %	+ 7 %	- 4 %	- 3 %
CARB vs High Sulfur [b]	+ 3 %	+ 8 %	- 6 %	- 16 %
On-Hwy vs High Sulfur [b]	+ 1 %	+ 1 %	- 3 %	- 13 %

Notes: a - EPA Line-Haul composite emissions
b - 4,670 ppm sulfur nonroad fuel.

Table 9 summarizes the smoke opacity levels measured for the three EMD locomotives. Summaries of the individual smoke test results for the three EMD locomotives are given in Appendices A through C. Although no formal statistical analysis of the smoke test results was performed by SwRI, inspection of the results given in Table 9 suggests that there were no major differences in smoke opacity between the three fuels for the three EMD locomotives tested.

TABLE 9. EMD SD70MAC SMOKE OPACITY SUMMARY

Locomotive / Fuel	Average Smoke Opacity [a], percent opacity		
	Maximum Steady State	30-Second Peak	3-Second Peak
BNSF No. 9693			
CARB fuel	11	14	20
On-Highway fuel	11	14	19
Nonroad High Sulfur fuel	12	16	22
BNSF No. 9754			
CARB fuel	19	25	28
On-Highway fuel	16	22	27
Nonroad High Sulfur fuel	13	20	24
BNSF No. 9696			
CARB fuel	11	13	21
On-Highway fuel	11	14	23
Nonroad High Sulfur fuel	12	15	26
Notes: a - Average of three tests on each fuel.			

B. **GE** - Table 10 gives average EPA line-haul composite emissions of HC, CO, NO_X, and PM for triplicate tests on each of the four fuels evaluated in the three GE locomotives. Recall that all three GE locomotives were tested with four fuels; the original three fuels, plus a 0.3 percent sulfur nonroad fuel (SwRI fuel code EM-2708-F). Individual test summaries for each of the three GE locomotives are given in Appendices D through F.

TABLE 10. GE DASH9-44CW EMISSIONS SUMMARY

Locomotive / Fuel	Average EPA Line-Haul Composite Emissions [a], g/hp-hr			
	HC	CO	NO_X	PM
UP No. 9724				
CARB fuel	0.40	1.4	11.2	0.14
On-Highway fuel	0.43	1.4	11.7	0.14
Nonroad High Sulfur fuel	0.40	1.4	12.2	0.23
0.3% Sulfur Nonroad fuel	0.41	1.4	11.9	0.19
UP No. 9715				
CARB fuel	0.33	2.9	10.6	0.13
On-Highway fuel	0.34	2.9	10.8	0.13
Nonroad High Sulfur fuel	0.32	3.0	11.5	0.21
0.3% Sulfur Nonroad fuel	0.33	3.0	11.2	0.17
UP No. 9733				
CARB fuel	0.32	3.3	10.8	0.13
On-Highway fuel	0.32	3.5	11.1	0.13
Nonroad High Sulfur fuel	0.30	3.5	11.5	0.20
0.3% Sulfur Nonroad fuel	0.30	3.5	11.4	0.17
Notes: a - Average of three tests on each fuel.				

Table 11 gives the average percent change in the line-haul composite emissions between test fuels for the three GE locomotives. CARB fuel reduced composite NO_X emissions by an average of 3 percent from levels for on-highway fuel, and by an average of 7 percent from levels for high-sulfur, nonroad fuel. These results are very consistent with the NO_X response observed for the EMD locomotives.

Using the 0.3 percent sulfur nonroad fuel as the basis of comparison, CARB fuel reduced composite NO_X emissions an average of 5 percent from levels for 0.3 percent sulfur, nonroad fuel. On-highway fuel reduced composite NO_X emissions by 2 percent compared to levels from the 0.3 percent sulfur, nonroad fuel. Table 11 also shows that switching from the high-sulfur (0.476 percent sulfur) fuel to the 0.3 percent sulfur fuel reduced the average composite NO_X emissions from the GE locomotives by 2 percent.

Composite PM emission levels for the three GE locomotives on a given fuel had less variation than was observed for the EMD locomotives. Table 11 gives the average percent difference in the weighted emissions between test fuels for the three GE locomotives. Using CARB fuel reduced the average composite PM emissions by an average of 3 percent compared to on-highway fuel, and by an average of 39 percent compared to high-sulfur, nonroad fuel. Using on-highway fuel, average composite PM emissions were reduced by 38 percent compared to high-sulfur, nonroad fuel.

TABLE 11. AVERAGE CHANGE IN REGULATED GE LOCOMOTIVE EXHAUST EMISSIONS BETWEEN LOCOMOTIVE TEST FUELS

FUEL CHANGE	Percent change in Average Line-Haul Composite Emissions [a]			
	HC	CO	NO_X	PM
CARB vs On-Hwy	- 4 %	- 1 %	- 3 %	- 3 %
CARB vs High Sulfur [b]	+ 2 %	- 2 %	- 7 %	- 39 %
On-Hwy vs High Sulfur [b]	+ 6 %	- 2 %	- 4 %	- 38 %
CARB vs 0.3% Sulfur [c]	+ 1 %	- 3 %	- 5 %	- 27 %
On-Hwy vs 0.3% Sulfur [c]	+ 4 %	- 2 %	- 2 %	- 25 %
0.3% Sulfur [c] vs High Sulfur [b]	+ 2 %	0 %	- 2 %	- 17 %

Notes: a - EPA Line-Haul duty cycle weighted emissions.
b - 4,670 ppm sulfur nonroad fuel, EM-2664-F
c - 0.3% Sulfur fuel = 3,190 ppm sulfur, EM-2708-F

Using the 0.3 percent sulfur nonroad fuel as the basis of comparison, CARB fuel reduced composite PM emissions an average of 27 percent compared to 0.3 percent sulfur, nonroad fuel, and using on-highway fuel reduced composite PM emissions by 25 percent compared to the 0.3 percent sulfur, nonroad fuel. Table 11 also shows that

switching to the 0.3 percent sulfur fuel from the high-sulfur (0.476 percent sulfur) fuel reduced the average PM emissions from the GE locomotives by 17 percent.

Table 12 summarizes the smoke opacity emissions for the three GE locomotives. Summaries of the individual smoke test results for the three GE locomotives are given in Appendices D through F. No statistical analysis of the smoke test results was performed by SwRI, but inspection of the results given in Table 12 suggests that there was no major change in smoke opacity results between the four fuels in the three GE locomotives.

TABLE 12. GE DASH9-44CW SMOKE OPACITY SUMMARY

Locomotive / Fuel	Average Smoke Opacity[a], percent opacity		
	Maximum Steady State	30-Second Peak	3-Second Peak
UP No. 9724			
CARB fuel	12	19	61
On-Highway fuel	12	18	62
Nonroad High Sulfur fuel	13	17	55
0.3% Sulfur Nonroad fuel	11	15	58
UP No. 9715			
CARB fuel	14	18	68
On-Highway fuel	9	14	64
Nonroad High Sulfur fuel	11	11	52
0.3% Sulfur Nonroad fuel	10	13	54
UP No. 9733			
CARB fuel	10	26	84
On-Highway fuel	10	23	79
Nonroad High Sulfur fuel	9	22	80
0.3% Sulfur Nonroad fuel	10	23	82
Notes: a - Average of three tests on each fuel.			

IV. UNREGULATED EMISSION TEST RESULTS

This section of the report presents results of unregulated emission measurements performed on each of the locomotives. Note that unregulated emissions were measured during one of three test runs on each of the three originally planned test fuels. Unregulated emissions were not measured with the 0.3 percent high-sulfur fuel.

A. Benzene and 1,3-Butadiene

Benzene and 1,3-butadiene emissions were measured on the first two of each of the EMD and GE locomotives, and the results are given in Appendix G. Table 13 and Figures 5 and 6 summarize the EPA line-haul duty-cycle weighted (composite) values for benzene and 1,3-butadiene emissions. In general, no specific trend in benzene or 1,3-butadiene emissions appeared as a function of fuel type for either the EMD or the GE locomotives. However, the GE locomotive engines had benzene emission levels roughly twice as high as the EMD locomotive engines, and 1,3-butadiene emission levels about 40 percent higher than the EMD engines.

TABLE 13. BENZENE AND 1,3-BUTADIENE EMISSIONS SUMMARY

Locomotive	EPA Line-Haul Composite Emissions					
	Benzene, mg/hp-hr			1,3-Butadiene, mg/hp-hr		
	CARB	On-Hwy	High S	CARB	On-Hwy	High S
EMD SD70MAC Locomotives						
BNSF No. 9693	1.02	1.64	0.76	1.40	1.60	1.60
BNSF No. 9754	0.48	0.18	0.15	1.10	1.31	1.28
BNSF No. 9696	**	**	**	**	**	**
Average EMD	**0.75**	**0.41**	**0.96**	**1.25**	**1.46**	**1.44**
GE DASH9-44CW Locomotives						
UP No. 9715	1.42	1.76	1.19	2.26	2.59	2.40
UP No. 9724	2.84	2.08	2.94	1.25	1.58	1.81
UP No. 9733	**	**	**	**	**	**
Average GE	**2.13**	**1.92**	**2.06**	**1.76**	**2.09**	**2.10**

Note: a - 4,760 ppm sulfur fuel, EM-2664-F.
** - 1,3-Butadiene was not measured during testing of BNSF No. 9696 or UP No. 9733.

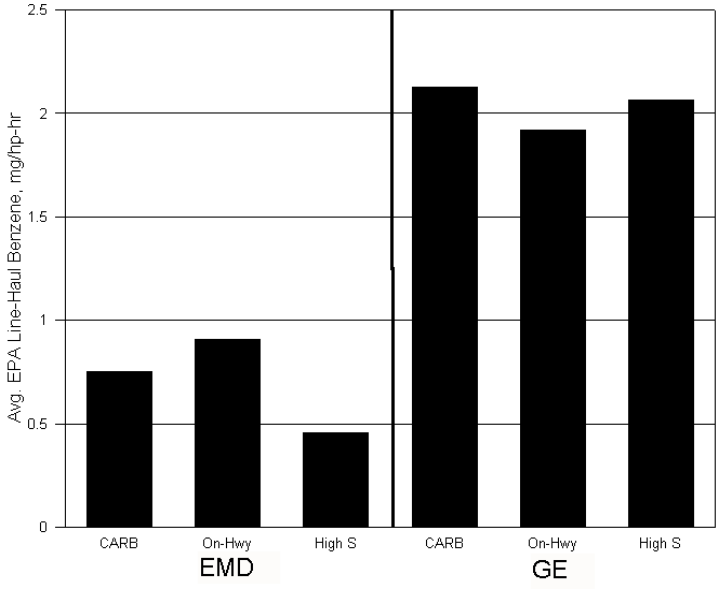

FIGURE 5. AVERAGE COMPOSITE BENZENE EMISSIONS

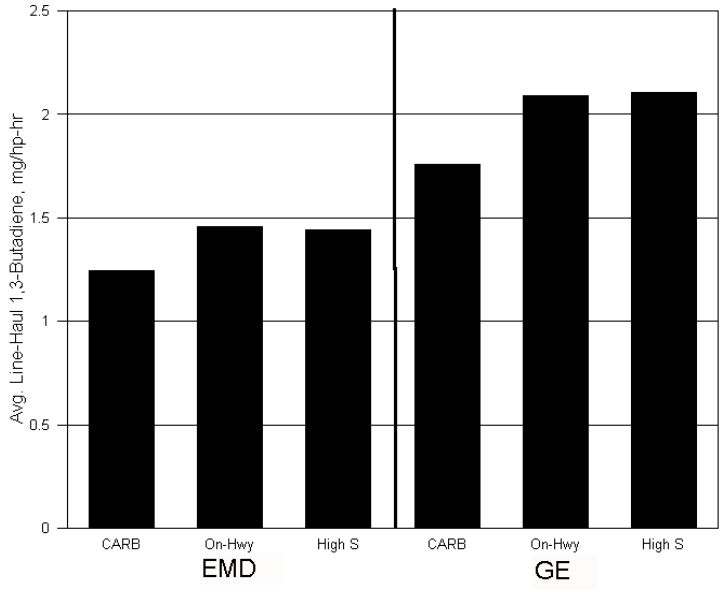

FIGURE 6. AVERAGE COMPOSITE 1,3-BUTADIENE EMISSIONS

B. Formaldehyde, Acetaldehyde, Acrolein

Formaldehyde, acetaldehyde, and acrolein emissions were measured on the first two of each of the EMD and GE locomotives, and the results are given in Appendix H. Table 14 and Figures 7 through 9 summarize the EPA line-haul composite values. In general, no trend in formaldehyde, acetaldehyde, or acrolein emissions appeared as a function of fuel type for either the EMD or the GE locomotives.

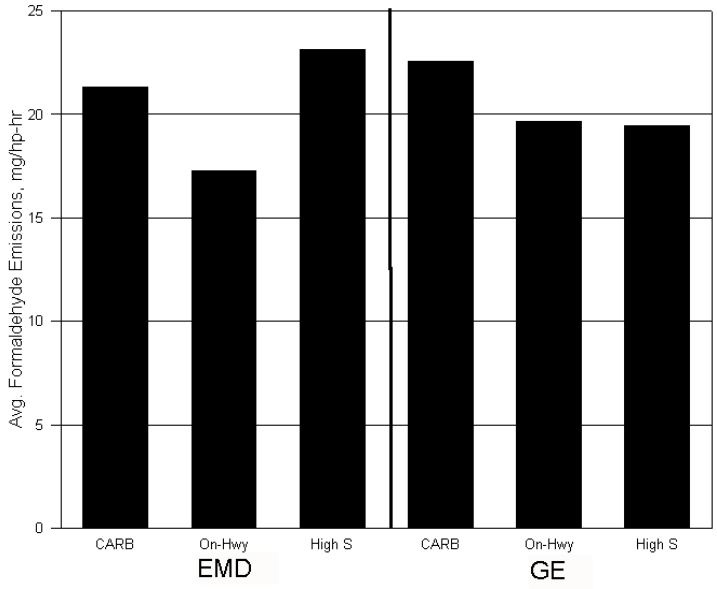

FIGURE 7. COMPOSITE FORMALDEHYDE EMISSIONS SUMMARY

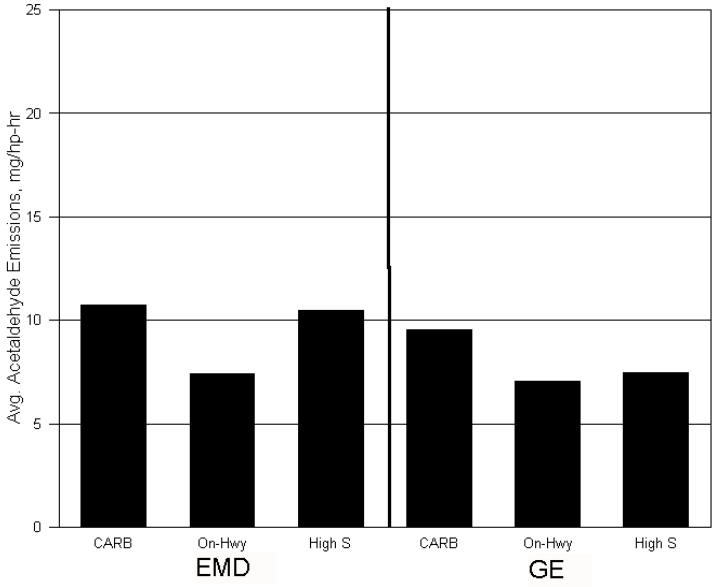

FIGURE 8. COMPOSITE ACETALDEHYDE EMISSIONS SUMMARY

TABLE 14. FORMALDEHYDE, ACETALDEHYDE, AND ACROLEIN EMISSIONS SUMMARY

Locomotive	EPA Line-Haul Composite Emissions								
	Formaldehyde, mg/hp-hr			Acetaldehyde, mg/hp-hr			Acrolein, mg/hp-hr		
	CARB	On-Hwy	High S	CARB	On-Hwy	High S	CARB	On-Hwy	High S
EMD SD70MAC Locomotives									
BNSF No. 9693	20.7	20.4	19.3	10.3	8.9	9.1	2.4	1.9	2.9
BNSF No. 9754	21.9	14.1	27.0	11.2	6.0	11.9	1.4	0.4	0.9
BNSF No. 9696	**	**	**	**	**	**	**	**	**
Average EMD	**21.3**	**17.3**	**23.1**	**10.7**	**7.4**	**10.5**	**1.9**	**1.1**	**1.9**
GE DASH9-44CW Locomotives									
UP No. 9715	23.8	17.7	16.4	11.0	6.5	6.1	3.3	0.9	0.7
UP No. 9724	21.3	21.6	22.4	8.1	7.6	8.8	0.9	1.1	1.0
UP No. 9733	**	**	**	**	**	**	**	**	**
Average GE	**22.6**	**19.6**	**19.4**	**9.5**	**7.0**	**7.4**	**2.1**	**1.0**	**0.9**

Note: a - 4,760 ppm sulfur fuel, EM-2664-F.
** -Aldehydes were not measured during testing of BNSF No. 9696 or UP No. 9733.

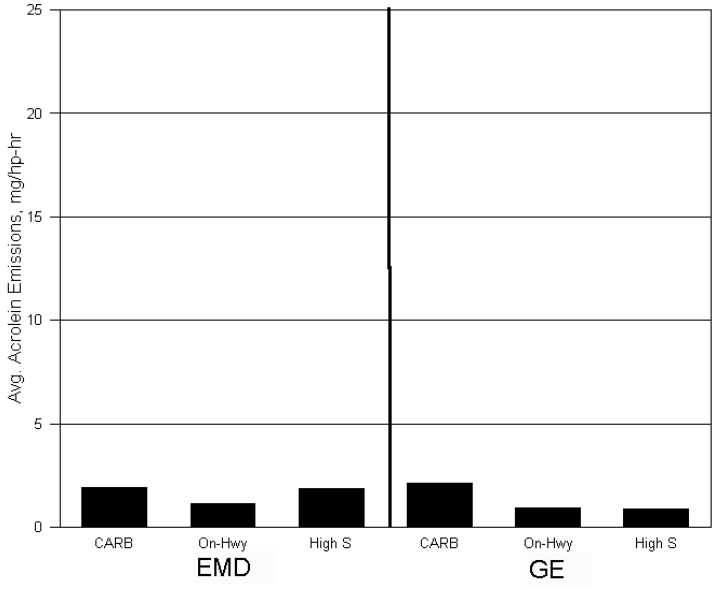

FIGURE 9. COMPOSITE ACROLEIN EMISSIONS SUMMARY

C. PAH

PAH emissions were measured on the first two of each of the EMD and GE locomotives, during one of the three tests on each of the three original test fuels. No PAH measurements were made while operating on the 0.3 percent sulfur nonroad fuel. Detailed PAH results are given in Appendix I, expressed on a mass emission rate basis (milligrams per hour), for each of the four locomotives, on each of the three fuels, at each throttle notch, for each of the nineteen PAH compounds, in both gas-phase and PM-phase. There is extensive PAH data included in Appendix I, and numerous ways to analyze and present the data. Spreadsheets of the PAH data were provided to ARB for analysis. For summary purposes, the individual throttle notch results were used to compute EPA line-haul composite PAH emission rates, expressed on a brake-specific basis in units of micrograms per horsepower-hour (µg/hp-hr). These results are given in Table 15. Also included in Table 15 is a summation of the total brake-specific PAH emissions for each locomotive on each test fuel, plus a separate summation of the vapor-phase PAH compounds, and the PM-phase PAH compounds. More than one significant figure is used in parts of Table 15 for completeness, but does not imply accuracy beyond one significant figure.

TABLE 15. EPA LINE-HAUL COMPOSITE PAH EMISSIONS

	GE UP No. 9724			GE UP No. 9715			EMD BNSF No. 9693			EMD BNSF No. 9754		
	CARB BS PAH µg/hp-hr	On-Hwy BS PAH µg/hp-hr	High S BS PAH µg/hp-hr	CARB BS PAH µg/hp-hr	On-Hwy BS PAH µg/hp-hr	High S BS PAH µg/hp-hr	CARB BS PAH µg/hp-hr	On-Hwy BS PAH µg/hp-hr	High S BS PAH µg/hp-hr	CARB BS PAH µg/hp-hr	On-Hwy BS PAH µg/hp-hr	High S BS PAH µg/hp-hr
PM Fraction												
NAPHTHALENE	16	16	12	8	5	6	0	0	0	12	3	5
2-METHYLNAPHTHALENE	8	8	5	1	1	0	1	2	3	3	2	2
ACENAPHTHYLENE	0	0	0	0	0	0	1	2	0	0	0	0
ACENAPHTHENE	2	2	1	0	0	0	0	0	0	1	1	0
FLUORENE	0	0	0	0	0	0	0	0	0	0	0	0
PHENANTHRENE	7	13	7	8	27	9	0	0	0	4	6	5
ANTHRACENE	1	1	0	1	2	0	5	10	5	0	0	0
FLUORANTHENE	15	15	15	10	13	13	0	1	0	2	3	3
PYRENE	21	29	16	14	27	10	4	5	4	6	12	7
BENZO(A)ANTHRACENE	3	4	3	1	2	2	8	14	7	1	1	1
CHRYSENE	5	6	7	3	4	7	0	1	1	1	2	2
BENZO(B)FLUORANTHENE	3	3	3	2	2	2	2	2	2	1	1	1
BENZO(K)FLUORANTHENE	3	3	3	1	1	2	0	1	1	0	0	0
BENZO(E)PYRENE	3	3	3	1	1	2	0	0	0	0	1	1
BENZO(A)PYRENE	2	2	1	1	1	1	0	1	0	0	0	0
PERYLENE	0	0	0	0	0	0	0	0	0	0	0	0
INDENO(123-CD)PYRENE	2	2	2	1	1	1	0	0	0	0	0	0
DIBENZ(AH)ANTHRACENE	0	0	0	0	0	0	0	0	0	0	0	0
BENZO(GHI)PERYLENE	3	3	1	1	1	1	0	0	0	0	1	0
Gas Phase												
NAPHTHALENE	1005	1894	1050	634	1457	982	0	0	0	26	38	0
2-METHYLNAPHTHALENE	572	515	475	200	504	478	0	6	25	226	430	218
ACENAPHTHYLENE	81	210	170	39	66	71	99	298	186	12	15	15
ACENAPHTHENE	4	26	15	1	6	6	0	0	1	1	3	2
FLUORENE	39	122	81	12	37	47	0	0	0	15	32	21
PHENANTHRENE	175	454	302	51	174	180	3	14	14	40	93	56
ANTHRACENE	18	52	28	3	9	9	28	63	55	4	7	5
FLUORANTHENE	20	37	41	6	11	11	2	4	4	3	4	3
PYRENE	21	56	34	6	18	8	2	2	2	4	8	3
BENZO(A)ANTHRACENE	0	0	0	0	0	0	1	4	2	0	0	0
CHRYSENE	0	0	0	0	0	0	0	0	0	0	0	0
BENZO(B)FLUORANTHENE	0	0	0	0	0	0	0	0	0	0	0	0
BENZO(K)FLUORANTHENE	0	0	0	0	0	0	0	0	0	0	0	0
BENZO(E)PYRENE	0	0	0	0	0	0	0	0	0	0	0	0
BENZO(A)PYRENE	0	0	0	0	0	0	0	0	0	0	0	0
PERYLENE	0	0	0	0	0	0	0	0	0	0	0	0
INDENO(123-CD)PYRENE	0	0	0	0	0	0	0	0	0	0	0	0
DIBENZ(AH)ANTHRACENE	0	0	0	0	0	0	0	0	0	0	0	0
BENZO(GHI)PERYLENE	0	0	0	0	0	0	0	0	0	0	0	0
EPA Line-Haul Weighted Total PAH (µg/hp-hr)	2,026	3,477	2,276	1,009	2,371	1,850	156	433	317	363	662	349
EPA Line-Haul Weighted PM-Phase PAH (µg/hp-hr)	92	111	80	55	89	58	22	41	26	33	32	27
EPA Line-Haul Weighted Vapor-Phase PAH (µg/hp-hr)	1,935	3,365	2,195	954	2,282	1,792	134	392	291	330	630	322

Figures 10 and 11 show the total composite PM-phase PAH and gas-phase PAH emissions, respectively.

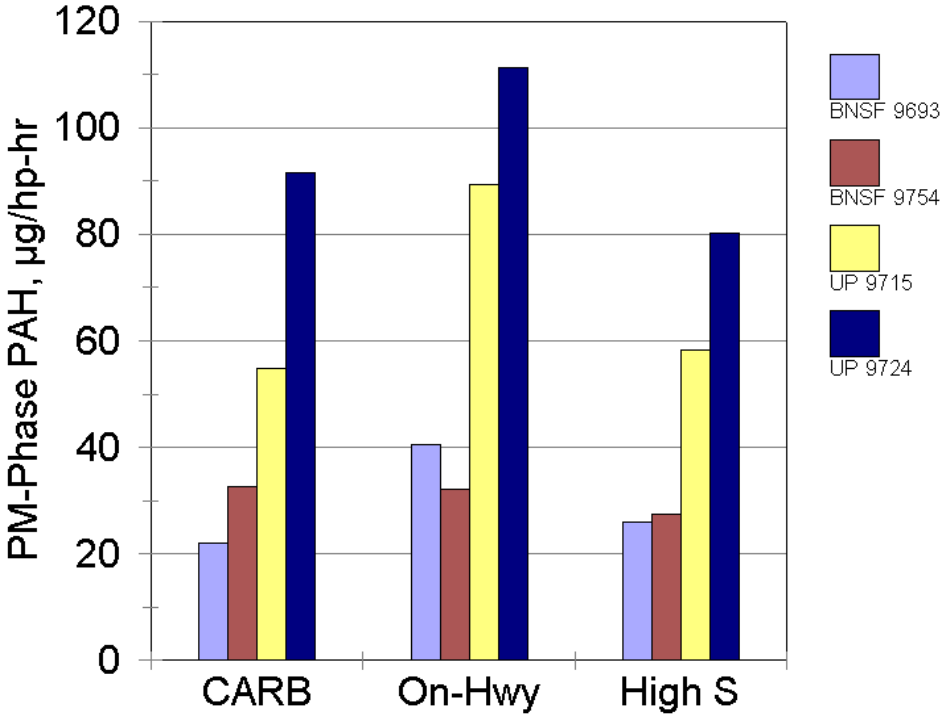

FIGURE 10. COMPOSITE PM-PHASE PAH EMISSIONS

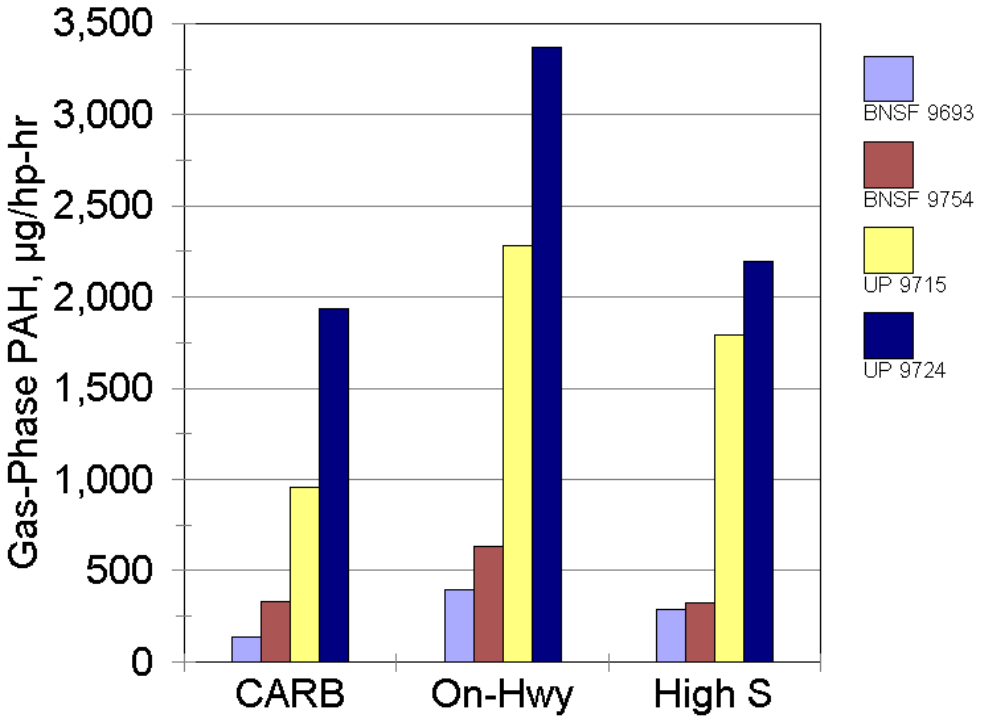

FIGURE 11. COMPOSITE GAS-PHASE PAH EMISSIONS

Several observations can be made from the PAH results given in Table 15, and in Figures 10 and 11. The total composite PAH emissions for the GE locomotives were roughly 6 times higher than for the EMD locomotives. PM-phase PAH emissions for the GE locomotives were three times higher than for the EMD locomotives, and the gas-phase PAH emissions were six to seven times higher. The higher PAH emissions of the GE engines were somewhat surprising, given that GE particulate levels were roughly half to a third those measured for the EMD locomotives.

From the PAH data, no major fuel effect on composite PAH emissions for the three fuels was apparent, even though the fuels differed in aromatic content. Recall that the CARB fuel was a blend of two commercially available "equivalent" fuels, which had an SFC aromatic level of 22.4 mass percent, compared to 30.1 percent for the on-highway fuel, and 29.5 percent for the high sulfur nonroad fuel (see Table 3).

D. Volatile Organic Fraction of total particulate (VOF)

The soluble organic fraction (SOF) analysis (which was also performed, and the results given in Section G) is more commonly used in PM health-effects assessments. The VOF analysis is important, however, when attempting to quantify the various sources that make up the total PM sampled.

Direct filter injection gas chromatography (DFI/GC) was used to measure the VOF of diesel particulate using the same 90mm Pallflex T60A20 filter collection media used for particulate mass determination. The contribution of unburned lubricating oil to VOF was also determined by an interpretive procedure based on simulated distillation boiling point distribution of a fresh lubricating oil sample. An external standard of locomotive engine lubricating oil was used to quantify the lubricating oil contribution to the VOF. Appendix J contains results from the analysis of selected particulate filters for determination of the VOF.

E. Metal Particulate

Metal particulate emissions were measured on two EMD locomotives and two GE locomotives. On one of the triplicate runs on each of the three original test fuels, PM was also sampled using 90mm Nucleopore filter media. These particulate-laden filters were analyzed to determine the weight fraction of metals present in the PM. This information was then used to compute the mass emission rate of metals in the exhaust.

Appendix K gives results from the PM metals analysis. PM metal mass emission rates are expressed in milligrams per hour at each throttle notch. For each element, at each notch, the value reported is either a “ND” for not detected, or the reported mass emission rate. For those reported as ND, there is an accompanying detection level for that element, at that operating condition. The detection limit was based on the detection limit of the ICP-AES instrument and the calibration standards used, and with the mass of PM accumulated on each filter, given the PM sampling conditions. Results reported as “trace” are those which had a elemental concentration above the detection limit, but less than three times the detection limit.

PM metal results in Appendix K show that chromium was the only metal that was measured above detection levels.

F. Sulfates

To isolate the specific effect of fuel sulfur content on changes in particulate emissions, sulfate analyses were performed for one of the three runs made on each fuel on each locomotive. Detailed results for individual tests are given in Appendix L, along with the EPA line-haul composite results.

Sulfate collected as particulate is generally composed of sulfuric acid, H_2SO_4, with associated bound water. The hydration state of the sulfuric acid is very sensitive to the relative humidity in the PM filter weighing chamber. Hence, the chamber humidity is controlled to 50 percent relative humidity to comply with the FTP. At 50 percent relative humidity in the weighing chamber, the hydration of the sulfuric acid results in 1.3 grams of water per gram of H_2SO_4. This hydration means that the fraction of the total particulate mass due to the sulfate is 2.3 times the mass of the "dry" sulfate alone, because of the associated water. Therefore, it should be noted that sulfate emissions summarized in Table 16 are reported as "wet" sulfate.

Results given in Table 16, and in Figure 12, show that for CARB fuel, which had a sulfur content of 50 ppm, sulfates contributed roughly 2 percent of the total PM from the three EMD locomotives tested, at an average composite level of 8 mg/hp-hr. The average composite wet sulfate emissions from the three GE locomotives using CARB fuel were also 8 mg/hp-hr, but because the total PM emissions for the GE locomotives were considerably lower than for the EMD locomotives, sulfate emissions contributed an average of 7 percent of the total composite PM emissions for the three GE locomotives.

The on-highway fuel had a fuel sulfur level of 330 ppm, but the sulfate emissions for both the EMD and GE locomotives were only slightly higher than were observed while operating on CARB fuel. For the EMD locomotives, the sulfate contributed 3 percent to the average total composite PM, or 10 mg/hp-hr. For the GE locomotives, the average composite wet sulfate emissions were 8 mg/hp-hr, which is the same as with CARB fuel.

The high-sulfur, nonroad fuel had a sulfur level of 4,760 ppm, and the increase in total PM due to sulfate was evident. For the EMD locomotives, wet sulfate contributed 15 percent to the total composite particulate, or 62 mg/hp-hr. For the GE locomotives, wet sulfate contributed 52 percent to the total composite particulate, or 118 mg/hp-hr.

TABLE 16. SULFATE EMISSIONS SUMMARY

Locomotive	EPA Line-Haul Composite "Wet" Sulfate Emissions [b]					
	CARB	On-Hwy	High S	CARB	On-Hwy	High S
	mg/hp-hr			% of Total PM		
EMD SD70MAC Locomotives						
BNSF No. 9693	9.9	8.6	60	2.4	2.0	11.9
BNSF No. 9754	7.5	8.4	68	1.9	2.2	15.2
BNSF No. 9696	5.6	14.1	60	2.4	5.5	19.1
Average EMD	**8**	**10**	**62**	**2**	**3**	**15**
GE DASH9-44CW Locomotives						
UP No. 9715	10.1	7.6	108.	8.1	5.9	45.8
UP No. 9724	9.8	9.6	138.	7.5	7.1	58.6
UP No. 9733	4.9	5.7	106.	4.5	4.6	52.8
Average GE	**8**	**8**	**118**	**7**	**6**	**52**

Note: a - 4,760 ppm sulfur fuel, EM-2664-F.
b - "Wet" sulfate = "dry" sulfate x 2.3

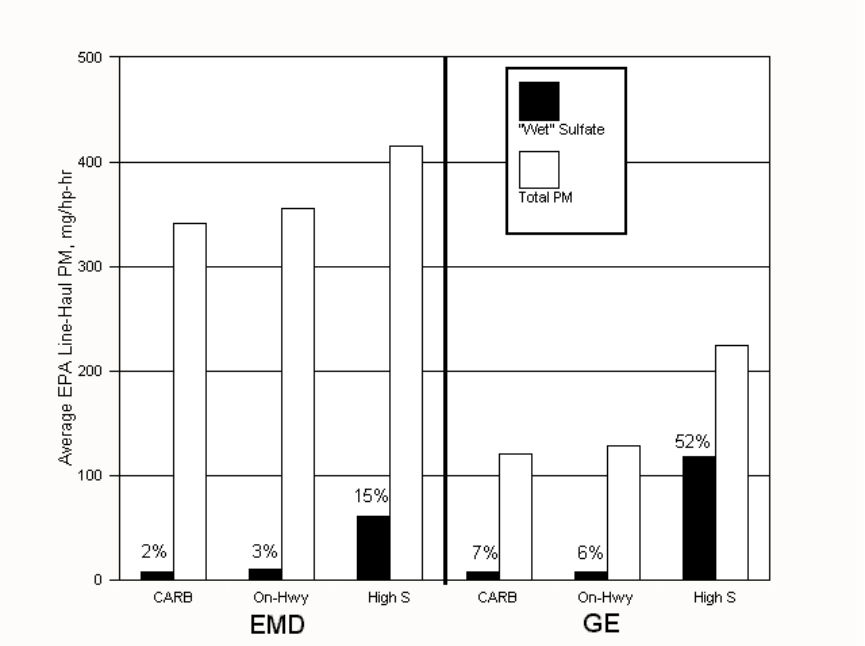

FIGURE 12. SULFATE EMISSIONS SUMMARY

G. Soluble Organic Fraction

Selected PM filters were analyzed to determine the SOF of the total particulate using a micro-soxhlet apparatus, in accordance with ARB's "Test Method for Soluble Organic Fraction (SOF) Extraction" dated April 1989. Resulting SOF levels were determined using the filter weight loss method. Essentially, SOF is any material (independent of boiling point) that is soluble in a 70 percent ethanol, 30 percent toluene mixture at specified test conditions. The only variance from the ARB SOF procedure was that the extraction was performed on a 40 percent "pie slice" of the 90 mm PM filter, instead of extracting a whole 47 mm diameter filter. This variance should not adversely affect the SOF results because the mass of material extracted would be similar.

SOF results are given in Appendix M, and EPA line-haul composite results are summarized in Table 17, and in Figure 13. The composite data show that the SOF of total particulate was very high for the EMD locomotives, at about 75 percent of the total PM. The SOF mass emission rate for the EMD locomotives is about four times higher than for the GE locomotives while operating on CARB fuel and the on-highway fuel, and roughly two times as high when using high-sulfur, nonroad fuel. For the GE locomotives, the average composite SOF was about 43 percent of total PM while operating on CARB fuel and the on-highway fuel, but composite SOF increased to 61 percent when operating on high-sulfur, nonroad fuel.

TABLE 17. SOF EMISSIONS SUMMARY

Locomotive	EPA Line-Haul Composite SOF Emissions					
	CARB	On-Hwy	High S	CARB	On-Hwy	High S
	mg/hp-hr			% of Total PM		
EMD SD70MAC Locomotives						
BNSF No. 9693	325	333	361	76	78	77
BNSF No. 9754	248	298	254	72	84	68
BNSF No. 9696	169	195	238	74	75	77
Average EMD	**247**	**275**	**284**	**74**	**79**	**74**
GE DASH9-44CW Locomotives						
UP No. 9715	55	59	113	43	42	56
UP No. 9724	67	71	143	47	49	65
UP No. 9733	44	49	125	40	38	61
Average GE	**56**	**60**	**127**	**43**	**43**	**61**
Note: a - 4,760 ppm sulfur fuel, EM-2664-F.						

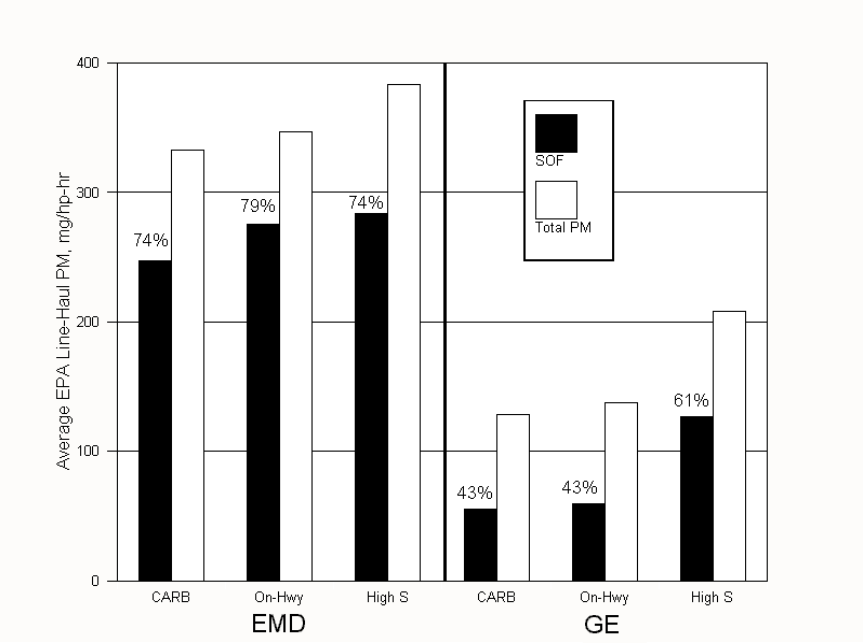

FIGURE 13. SOF OF PM EMISSIONS SUMMARY

V. DDC SERIES 60 DIESEL ENGINE TEST RESULTS

In recent years, many diesel fuel-effects studies have been performed using a Detroit Diesel Corporation (DDC) Series 60 heavy-duty diesel engine. This engine has been used to screen candidate CARB diesel fuel formulations since the late 1980's, and its use is permitted in Title 13 of the California Code of Regulations, Section 2282(g)(4)(A) for certifying a diesel fuel formulation for mobile sources in California. The two batches of fuel from California that were blended to make the CARB fuel used in the locomotive fuel effects project were commercially available CARB-approved equivalent diesel fuel formulations that at one time were qualified in the DDC Series 60 engine.

Given the fact that the CARB fuel used in the locomotive study was a blend of two commercially available CARB fuel formulations, rather than a true CARB reference fuel with an aromatic content of less than 10 percent, the question was raised as to how the CARB fuel blend would compare to the other locomotive test fuels when tested in the DDC Series 60 engine. To answer this question, ARB requested that SwRI run selected locomotive test fuels in the Series 60 engine to assess emissions.

ARB selected three of the four locomotive project test fuels for testing in for the Series 60 engine. The three fuels were CARB fuel, on-highway fuel, and the 0.3 percent sulfur nonroad fuel. Selected properties for all four of the locomotive study test fuels are given in Table 3. Only the 0.476 percent sulfur nonroad fuel used in locomotive testing was not used in the Series 60 tests.

The three locomotive fuels were tested using a 1991 model year 12.7 liter DDC Series 60 engine (SN 06RE001123), with a rated power of 370 hp at a speed of 1,800 rpm, and a peak torque of 1,450 lb-ft at a speed of 1,200 rpm. Transient emission tests were conducted according to the EPA Federal Test Procedure (FTP), as specified in the Code of Federal Regulations (CFR), Title 40, Part 86, Subpart N, “Emission Regulations for New Otto-Cycle and Diesel Heavy-Duty Engines: Gaseous and Particulate Exhaust Test Procedures.”

The CARB-equivalent diesel fuel qualification protocols require only transient cycle tests, which are also required for EPA certification of heavy-duty on-highway diesel engines. For this work, four hot-start transient tests on each of the three fuels were run. In addition, ARB requested that selected steady-state tests be run, which could be directly compared to the locomotive test data, which were generated from steady-state tests.

Three steady-state modes were used in the Series 60 tests: rated power to simulate Notch 8 locomotive operation; idle for locomotive Idle, and a condition that represented the Notch 5 engine speed on the GE locomotive, which for the DDC engine was 1,700 rpm, and a load of 540 ft-lb. The three steady-state test modes were then duty-cycle weighted using an "AAR 3-mode" weighting factor developed by SwRI for AAR-funded locomotive testing in the early 1990s. The AAR 3-mode duty cycle weighting factors are 25 percent Notch 8, 25 percent Notch 5, and 50 percent Idle. The AAR 3-mode duty cycle, or AAR-composite, has been shown to give results similar to those obtained for the EPA line-haul duty cycle composite.

Presented in Table 18 are the regulated emission results from four hot-start transient tests on the three locomotive test fuels. Individual transient-cycle test data sheets are given in Attachment N. Table 18 also gives the average results of the four tests, and the difference between the three fuels, expressed as percent change. Comparing CARB fuel to the 0.3 percent sulfur nonroad fuel, CARB fuel resulted in 8.3 percent lower NO_X, and 23.8 percent lower PM. These test results agree with the NO_X and PM reductions that ARB attributes to the overall CARB diesel fuel program, which is a 7 percent reduction in NO_X, and a 25 percent reduction in PM. Comparing the CARB fuel to the Federal on-highway fuel, the CARB fuel had 5.2 percent lower NO_X, but the PM reduction was only 3.9 percent.

Table 19 gives results from an analysis of the composition of the particulate collected from the transient cycle tests. For each transient-cycle test, particulate was sampled using a pair of 90mm diameter Pallflex T60A20 fluorocarbon-coated glass-fiber filters. Presented below is a discussion of the PM filter analysis results.

A portion of each filter was analyzed to determine the SOF of the total particulate using a micro-soxhlet apparatus, in accordance with ARB's "Test Method for Soluble Organic Fraction (SOF) Extraction" dated April 1989. Resulting SOF levels were determined using the filter weight loss method. Essentially, SOF is any material (independent of boiling point) that is soluble in a 70 percent ethanol, 30 percent toluene mixture at specified test conditions. The only variance from the ARB SOF procedure was that the extraction was performed on a 40 percent "pie slice" of the 90 mm PM filter, instead of extracting a whole 47 mm diameter filter. This variance should not adversely affect the SOF results, because the mass of material extracted would be similar.

Results given in Table 19 show that the SOF of total particulate was essentially the same for CARB fuel and on-highway fuel. For both fuels, about 28 percent of the total PM

was SOF, with a brake-specific SOF of 0.057 g/hp-hr. When using the 0.3 percent sulfur nonroad fuel, the SOF increased to 38.5 percent of the total PM, with a brake specific SOF level almost twice as high as the other two fuels, at 0.102 g/hp-hr.

TABLE 18. DDC SERIES 60 TRANSIENT FTP TEST RESULTS USING LOCOMOTIVE TEST FUELS

Test Fuel	HC, g/hp-hr	CO, g/hp-hr	NO_x, g/hp-hr	PM, g/hp-hr	bsfc, lb/ hp-hr
CARB fuel					
Hot 1	0.098	2.311	4.286	0.205	0.378
Hot 2	0.094	2.253	4.455	0.205	0.379
Hot 3	0.109	2.225	4.350	0.198	0.372
Hot 4	0.084	2.255	4.373	0.197	0.376
Average	0.096	2.261	4.366	0.201	0.376
On-Highway fuel					
Hot 1	0.117	2.356	4.609	0.209	0.368
Hot 2	0.212	2.365	4.591	0.206	0.373
Hot 3	0.124	2.481	4.645	0.213	0.376
Hot 4	0.111	2.411	4.580	0.210	0.375
Average	0.118	2.403	4.606	0.210	0.373
0.3 % Sulfur Nonroad fuel					
Hot 1	0.105	2.567	4.756	0.272	0.375
Hot 2	0.109	2.510	4.678	0.276	0.372
Hot 3	0.114	2.520	4.838	0.252	0.371
Hot 4	0.096	2.441	4.778	0.256	0.371
Average	0.106	2.510	4.763	0.264	0.372
Percent Change in Average Transient Hot-Start Emissions					
CARB vs. 0.3% S Nonroad	-9.2 %	-9.9 %	-8.3 %	-23.8 %	+1.1 %
On-Highway vs 0.3% S Nonroad	+11.6 %	-4.2 %	-3.3 %	-20.6 %	+0.2 %
CARB vs. On-Highway	-18.6 %	-5.9 %	-5.2 %	-3.9 %	+0.9 %

TABLE 19. DDC SERIES 60 TRANSIENT FTP PM ANALYSIS

Test	Total PM, g/hp-hr	SOF, % of Total PM	SOF, g/hp-hr	VOF, % of Total PM	VOF, g/hp-hr	Dry Sulfate, mg/hp-hr	"Wet" Sulfate, mg/hp-hr	"Wet" Sulfate, % of Total PM	Est. Carbon Soot, g/hp-hr	Est. Carbon Soot, % of Total PM
CARB Hot 1	0.205	30.0 %	0.061	19.9 %	0.041	1.1	2.6	1.2 %	0.612	78.9 %
CARB Hot 2	0.205	27.6 %	0.057	19.7 %	0.040	0.9	2.1	1.0 %	0.163	79.3 %
CARB Hot 3	0.198	26.7 %	0.053	13.0 %	0.026	0.6	1.4	0.7 %	0.171	86.3 %
CARB Hot 4	0.196	nd [a]	nd [a]	19.8 %	0.039	0.7	1.5	0.8 %	0.156	79.4 %
CARB Average	0.201	28.1 %	0.057	18.1 %	0.036	0.8	1.9	0.9 %	0.163	81.0 %
On-Hwy Hot 1	0.209	28.7 %	0.060	19.7 %	0.041	3.2	7.4	3.5 %	0.160	76.8 %
On-Hwy Hot 2	0.206	23.2 %	0.048	18.2 %	0.037	3.2	7.4	3.6 %	0.161	78.3 %
On-Hwy Hot 3	0.213	29.8 %	0.063	18.6 %	0.040	2.7	6.2	2.9 %	0.167	78.5 %
On-Hwy Hot 4	0.210	nd [a]	nd [a]	19.7 %	0.041	3.1	7.1	3.4 %	0.162	76.9 %
On-Hwy Average	0.210	27.2 %	0.057	19.0 %	0.040	3.0	7.0	3.3 %	0.163	77.6 %
0.3% S Hot 1	0.272	39.1 %	0.106	13.2 %	0.036	30.7	70.5	25.9 %	0.166	60.9 %
0.3% S Hot 2	0.276	38.1 %	0.105	13.2 %	0.037	31.5	72.5	26.3 %	0.167	60.5 %
0.3% S Hot 3	0.252	36.7 %	0.092	14.1 %	0.035	25.5	58.6	23.2 %	0.158	62.7 %
0.3% S Hot 4	0.256	40.2 %	0.103	13.9 %	0.036	26.7	61.5	24.0 %	0.159	62.1 %
0.3% S Average	0.264	38.5 %	0.102	13.6 %	0.036	28.6	65.8	24.9 %	0.162	61.5 %
Percent Change for Average										
CARB vs. 0.3% S	-24 %	-27 %	-44 %	33 %	2 %	-97 %	-97 %	-96 %	0 %	32 %
On-Highway vs 0.3% S	-21 %	-29 %	-44 %	40 %	11 %	-89 %	-89 %	-87 %	0 %	26 %
CARB vs. On-Highway	-4 %	3 %	0 %	-5 %	-9 %	-73 %	-73 %	-72 %	0 %	4 %

Notes: a - not determined
b - carbon soot estimated by subtracting VOF and wet sulfate from the total PM.

Another portion of each particulate-laden filter was analyzed to determine the VOF of total PM. The analytical technique used to determine the VOF is known as Direct Filter Injection Gas Chromatography (DFI/GC). One significant advantage to the DFI/GC method over other methods (e.g., SOF) is that no solvent extraction procedure is required to obtain a sample for subsequent analyses. DFI/GC is commonly used in diesel engine development because it provides a qualitative assessment of the relative contributions of fuel and unburned lubricating oil to the VOF. The DFI/GC procedure is described in Section II.F of this report.

DFI/GC analysis was used to measure the VOF of the transient test cycle particulate emissions using a portion of the same filter collection media used for SOF determination. Table 19 summarizes the VOF results from the transient tests performed using the three locomotive fuels. As a percentage of total PM, the VOF values for the CARB and on-highway fuels were very similar, at 18 to 19 percent VOF. The average percentage of VOF for the 0.3 percent sulfur, nonroad fuel was 14 percent. The brake-specific VOF for all three fuels was very similar, ranging from about 0.036 to 0.040 g/hp-hr.

The VOF data for the 0.3 percent sulfur nonroad fuel was notably different from the SOF data. Recall that the average SOF level using the 0.3 percent sulfur nonroad fuel was roughly twice as high as for the other two fuels, 0.057 verses 0.102 g/hp-hr. The 0.102 g/hp-hr SOF level for the 0.3 percent sulfur nonroad fuel is nearly three times higher than the average VOF result of 0.036 g/hp-hr. This difference suggests that the sulfate and other sulfur-containing compounds, and associated water, may have been physically removed from the filter during the SOF extraction process, and inadvertently included as SOF. This observation raises concern over the possibility of double-counting sulfate compounds in PM filter analysis, where sulfur compounds are counted once as sulfate, and potentially again as part of the SOF. This double-counting could lead to erroneously low estimates of the carbon soot fraction of PM. These errors would be proportional to the sulfur content of the fuel, with higher sulfur fuels having the largest potential for error.

To isolate the specific effect of fuel sulfur content on change in particulate emissions, sulfate analyses were performed. Sulfate emissions from the transient test cycles run on the DDC Series 60 engine are summarized in Table 19. Sulfate is reported as “wet” sulfate, because sulfate particulate is generally composed of sulfuric acid, H_2SO_4, with associated bound water. At 50 percent relative humidity used in the weighing chamber, the hydration of the sulfuric acid results in 1.3 grams of water per gram of H_2SO_4. This hydration means that the fraction of the total particulate mass due to the sulfate is 2.3 times the mass of the “dry” sulfate alone, because of the associated water. Results given

in Table 19 show that for CARB fuel, which had a sulfur content of 50 ppm, sulfates contributed only 0.9 percent of the total PM, or 1.9 mg/hp-hr. The on-highway fuel had a fuel sulfur level of 330 ppm, and the sulfate contributed an average of 3.3 percent of the total PM, or 7.0 mg/hp-hr. The nonroad fuel had a sulfur level of 3,190 ppm, and sulfate contributed an average 24.9 percent of the total particulate, or 65.8 mg/hp-hr.

Table 19 also gives an estimate of the amount of carbon soot in the PM. Carbon soot was estimated by subtracting the VOF and the "wet" sulfate portions from the total PM. The remainder was considered to be carbon soot. Inspection of the data in Table 19 shows that the estimated mass of carbon soot in total PM is essentially the same for all three fuels. Recall that the VOF was also essentially the same for all three fuels, leaving variation in sulfates as the principal cause for changes in PM emissions among the three fuels tested.

Steady-state test results are given in Table 20 in the form of 3-mode AAR-composite values. Detailed test data for the individual steady-state tests on the DDC Series 60 engine are given in Appendix N. The original test plan called for duplicate 3-mode tests using each fuel. However, due to variability in NO_X and PM results during tests with CARB fuel, three additional tests were run using CARB fuel. All the test results are included in Table 20.

Table 20 also gives the average AAR-composite results, and the difference between emissions for the three fuels, expressed as percent change. Comparing CARB fuel to the 0.3 percent sulfur nonroad fuel, CARB fuel resulted in 5.1 percent lower NO_X, and 37.3 percent lower PM.

Presented in Table 21 is a summary of both transient and steady-state emission results from the DDC Series 60 engine, along with the average change in emissions observed for the three GE locomotives and the three EMD locomotive engines. Note that no tests were run on the EMD locomotives using the 0.3 percent sulfur nonroad fuel, but data for the EMD engines operating on the 0.476 percent sulfur fuel is included for comparison purposes

The data in Table 21 show that during steady-state operation, the NO_X response of the DDC engine was very similar to that observed for both the GE and EMD locomotives. However, during transient operation, the NO_X response of the DDC engine was stronger than observed during steady-state tests.

TABLE 20. DDC SERIES 60 3-MODE AAR-COMPOSITE STEADY-STATE TEST RESULTS USING LOCOMOTIVE TEST FUELS

Test	HC, g/hp-hr	CO, g/hp-hr	NO_x, g/hp-hr	PM, g/hp-hr	bsfc, lb/ hp-hr
CARB fuel					
Run 1	0.040	0.482	8.236	0.091	0.331
Run 2	0.043	0.497	8.005	0.072	0.326
Run 3	0.035	0.567	8.396	0.082	0.339
Run 4	0.033	0.519	8.059	0.069	0.327
Run 5	0.038	0.525	8.059	0.072	0.330
Average	0.038	0.518	8.158	0.077	0.331
On-Highway fuel					
Run 1	0.058	0.547	8.389	0.084	0.330
Run 2	0.061	0.567	8.397	0.091	0.329
Average	0.059	0.557	8.393	0.087	0.329
0.3 % Sulfur Nonroad fuel					
Run 1	0.026	0.597	8.464	0.131	0.322
Run 2	0.054	0.561	8.729	0.116	0.327
Average	0.040	0.579	8.596	0.123	0.325
Percent Change in Average 3-Mode AAR-Composite Steady-State Emissions					
CARB vs. 0.3% S Nonroad	-6.3 %	-10.5 %	-5.1 %	-37.3 %	+1.8 %
On-Highway vs 0.3% S Nonroad	+47.0 %	-3.8 %	-2.4 %	-29.2 %	+1.4 %
CARB vs. On-Highway	-36.3 %	-7.0 %	-2.8 %	-11.4 %	+0.4 %

TABLE 21. COMPARISON OF FUEL EFFECTS ON LOCOMOTIVES AND A DDC SERIES 60 ENGINE

Test Cycle / Engine	HC, g/hp-hr	CO, g/hp-hr	NO_x, g/hp-hr	PM, g/hp-hr
CARB vs. 0.3% S Nonroad				
DDC Series 60 - Transient	-9.6 %	-9.9 %	-8.3 %	-23.8 %
DDC Series 60 - AAR 3-Mode SS	-6.3 %	-10.5 %	-5.1 %	-37.3 %
GE DASH9-44CW [a]	+0.6 %	-2.7 %	-5.4 %	-26.7 %
EMD SD70MAC [b,c]	+2.6 %	+8.1 %	-6.0 %	-16.0 %
On-Highway vs 0.3% S Nonroad				
DDC Series 60 - Transient	+11.6 %	-4.2 %	-3.3 %	-20.6 %
DDC Series 60 - AAR 3-Mode SS	+47.0 %	-3.8 %	-2.4 %	-29.2 %
GE DASH9-44CW [a]	+4.4 %	-1.7 %	-2.5 %	-24.7 %
EMD SD70MAC [b,c]	+1.3 %	+1.3 %	-2.5 %	-13.2 %
CARB vs. On-Highway				
DDC Series 60 - Transient	-18.6 %	-5.9 %	-5.2 %	-3.9 %
DDC Series 60 - AAR 3-Mode SS	-36.3 %	-7.0 %	-2.8 %	-11.4 %
GE DASH9-44CW [a]	-3.6 %	-1.0 %	-3.0 %	-2.7 %
EMD SD70MAC [b]	+1.4 %	+6.9 %	-3.5 %	-3.2 %

Notes: a - Average of the three GE locomotives tested, using the EPA line-haul duty cycle.
b - Average of the three EMD locomotives tested, using the EPA line-haul duty cycle.
c - The EMD locomotives were not tested with the 0.3 percent sulfur fuel. Data shown is for tests run using the 0.476 percent sulfur nonroad fuel.

Transient PM emission response for the DDC engine was generally similar to that observed for the GE locomotive. The fuel effect on PM emissions for the two-stroke EMD locomotives was roughly half that observed on GE locomotives. This difference is due to the relatively high PM emission level of the EMD locomotives, compared to that of the GE locomotives and the DDC Series 60 engine. A significant portion of the EMD PM is VOF attributable to lubricating oil consumption, and as such, a large portion of the PM is unaffected by fuel type. Therefore, the observed change in PM emissions as a function of fuel type is smaller.

VI. SUMMARY

This report documents results from test work intended to assess changes in locomotive exhaust emissions with changes in the type of diesel fuel used. In this project, three commercially available fuels were tested in a total of six 4,000 to 4,400 hp line-haul locomotives; three manufactured by the Electro-Motive Division of General Motors Corporation (EMD), and three manufactured by the Transportation Systems Division of the General Electric Company (GE). The commercially available fuels included a CARB fuel, a Federal on-highway fuel, and high-sulfur, nonroad fuel. Due to the fact that the sulfur level of the "high- sulfur" fuel was higher than nonroad diesel fuel typically purchased by the railroads, a fourth fuel was also used in the three GE locomotives, which was a nonroad fuel with a sulfur level of 3,190 ppm (0.32 percent). In this report, this fourth fuel is referred to as the "0.3 percent sulfur" fuel, and is considered to be more representative of high sulfur nonroad diesel fuels used by the railroads. Test results from the program were provided to ARB and the AAR for detailed analysis.

Focusing on the major changes in EPA line-haul composite emissions that occurred with the different fuels, Table 22 summarizes the percent changes in regulated exhaust emissions that occurred when switching fuels. Compared to the high-sulfur, nonroad diesel fuel, average composite NO_X emissions were 6-7 percent lower with CARB fuel, which corresponds to about 0.8 g/hp-hr. This level of NO_X reduction is similar to the reduction observed for on-highway diesel engines.

Figure 14 shows the effect of test fuel sulfur content on the composite PM emissions from the two models of locomotives tested. The PM reduction with CARB fuel was largely attributable to the reduced sulfur content of the fuel, and on a g/hp-hr basis, the response to PM was essentially the same for each locomotive model. Sulfate analysis performed on the PM samples quantified the contribution of sulfate to total PM emissions.

Changes to composite HC and CO emissions with CARB fuel and the high-sulfur nonroad fuel were mixed, and did not show any strong trends. There was little change in smoke, as well. However, it is anticipated that ARB and AAR statistical analyses of the data will determine what changes in emissions are statistically significant.

Detailed test results for selected unregulated emissions, including benzene, 1,3-butadiene, formaldehyde, acetaldehyde, acrolein, gas-phase and PM-phase PAH compounds, the volatile organic fraction of total particulate, PM metals, sulfates, and the

soluble organic fraction, are included in this report. Notable changes in sulfate and SOF were observed between the test fuels, with the CARB fuel demonstrating considerable reductions in both sulfate and SOF. No statistical analyses of data was performed as part of this program.

TABLE 22. AVERAGE CHANGE IN REGULATED LOCOMOTIVE EXHAUST EMISSIONS BETWEEN TEST FUELS

FUEL CHANGE	Percent change in Average Line-Haul Composite Emissions [a]			
	HC	CO	NO_x	PM
EMD SD70MAC				
CARB vs. On-Hwy	+ 1 %	+ 7 %	- 4 %	- 3 %
CARB vs High Sulfur [b]	+ 3 %	+ 8 %	- 6 %	- 16 %
On-Hwy vs High Sulfur [b]	+ 1 %	+ 1 %	- 3 %	- 13 %
GE DASH9-44CW				
CARB vs On-Hwy	- 4 %	- 1 %	- 3 %	- 3 %
CARB vs High Sulfur [b]	+ 2 %	- 2 %	- 7 %	- 39 %
On-Hwy vs High Sulfur [b]	+ 6 %	- 2 %	- 4 %	- 38 %
CARB vs 0.3% Sulfur [c]	+ 1 %	- 3 %	- 5 %	- 27 %
On-Hwy vs 0.3% Sulfur [c]	+ 4 %	- 2 %	- 2 %	- 25 %

Notes: a - EPA Line-Haul duty cycle weighted emissions.
b - 4,670 ppm sulfur nonroad fuel, EM-2664-F
c - 0.3% Sulfur fuel = 3,190 ppm sulfur, EM-2708-F

When the locomotive test fuels were evaluated in a DDC Series 60 diesel engine, which was the engine used to qualify equivalent CARB fuel formulations, results showed that during steady-state operation, the NO_X response of the DDC engine to the locomotive test fuels was very similar to that observed on the GE and EMD locomotives. During transient operation, the NO_X response of the DDC engine was consistently stronger than observed during steady-state tests. PM response of the DDC engine as a function of fuel type was generally similar to that observed for the GE locomotive.

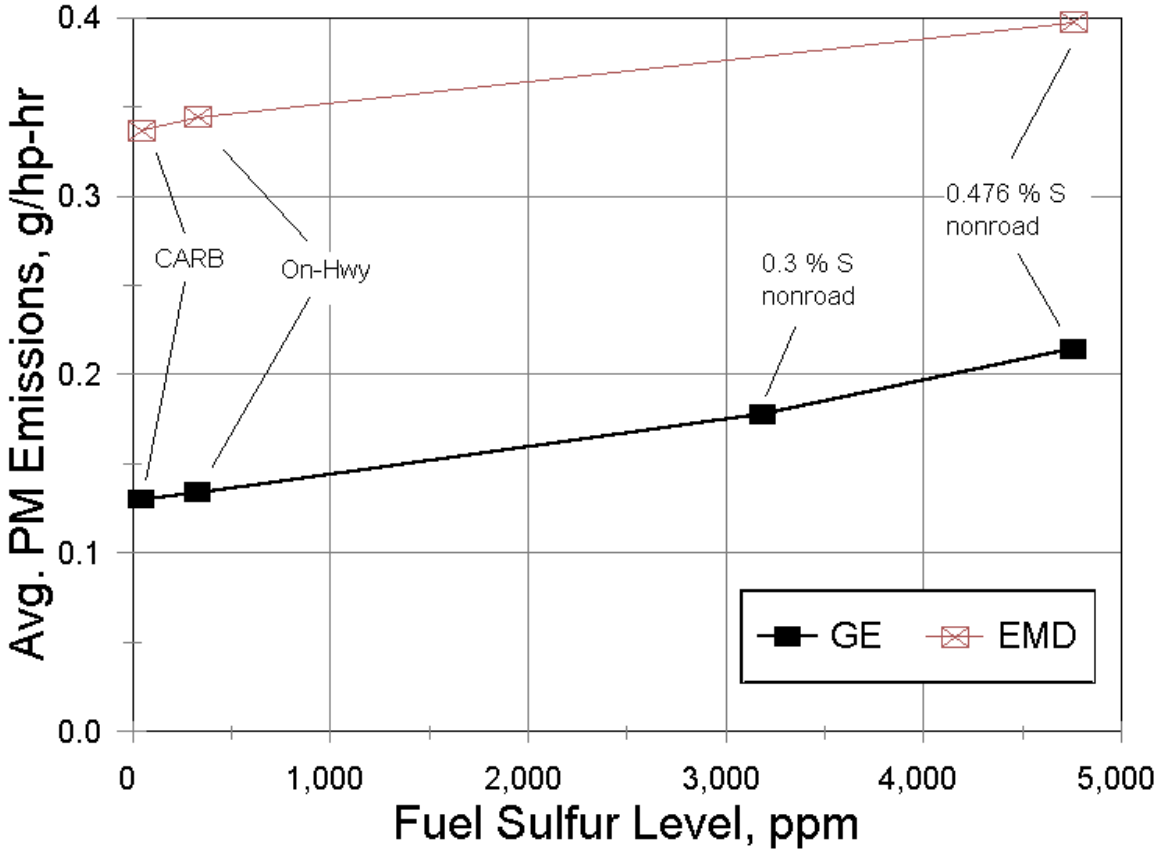

FIGURE 13. EFFECT OF TEST FUEL SULFUR CONTENT ON PM EMISSIONS

Appendix O to this report documents results from exhaust particulate size distribution measurements performed on one of the three GE locomotives tested, UP No. 9724. For the particulate size determination work reported in Appendix O, two fuels were compared; CARB diesel and a nonroad diesel fuel with a fuel sulfur level of 0.3 percent (3,190 ppm). Tests were run at only two operating conditions: Idle and Notch 8 (rated power). Particle size distribution was measured using a Model 110 micro-orifice uniform deposit impactor (MOUDI). Additional analysis of the size-segregated particulate included determination of the volatile organic fraction (VOF), elemental analysis, and anion and cation analyses.

LIST OF APPENDICES

APPENDIX A-1

BNSF No. 9693 Test Summary

EPA Line-Haul Duty Cycle Weighting Factors

BNSF 9693 SUMMARY
EMD SD70MAC

Updated 06-29-99 sgf

	obs bsfc lb/hp-hr	HC g/hp-hr	CO g/hp-hr	EPA NOx g/hp-hr	KH-NOx g/hp-hr	PM g/hp-hr	
Carb Diesel (EM-2663-F)							
	0.353	0.338	2.586	11.119	10.958	0.425	
	0.355	0.342	3.027	10.981	10.797	0.449	
	0.354	0.321	2.795	10.983	10.739	0.414	
Avg	0.354	0.334	2.803	11.028	10.831	0.430	
cov	0.3%	3.3%	7.9%	0.7%	1.0%	4.2%	
On-Highway Diesel (EM-2677-F)							
	0.354	0.314	2.509	11.452	11.178	0.427	
	0.355	0.319	2.644	11.471	11.340	0.422	
	0.357	0.341	2.673	11.128	10.915	0.426	
Avg	0.355	0.325	2.608	11.351	11.144	0.425	
cov	0.4%	4.3%	3.4%	1.7%	1.9%	0.5%	
Nonroad High Sulfur Diesel (EM-2664-F)							
	0.357	0.236	2.376	11.526	11.300	0.469	
	0.356	0.346	2.402	11.905	11.703	0.521	
	0.357	0.364	2.334	11.913	11.697	0.504	
Avg	0.356	0.315	2.370	11.781	11.567	0.498	
cov	0.2%	22.0%	1.4%	1.9%	2.0%	5.4%	
	-0.7%	6%	18%	-6%	-6%	-14%	carb vs HS
	-0.3%	3%	10%	-4%	-4%	-15%	on-hwy vs HS
	-0.4%	3%	7%	-3%	-3%	1%	carb vs on-hwy

EPA Switch Cycle Weighting Factors

	obs bsfc lb/hp-hr	HC g/hp-hr	CO g/hp-hr	EPA NOx g/hp-hr	KH-NOx g/hp-hr	PM g/hp-hr	
Carb Diesel (EM-2663-F)							
	0.410	0.565	2.209	11.697	11.499	0.323	
	0.414	0.499	2.397	11.814	11.597	0.321	
	0.413	0.531	2.287	11.690	11.513	0.346	
Avg	0.412	0.531	2.298	11.734	11.536	0.330	
cov	0.4%	6.2%	4.1%	0.6%	0.5%	4.2%	
On-Highway Diesel (EM-2677-F)							
	0.415	0.550	2.249	12.043	11.745	0.303	
	0.413	0.492	2.242	12.129	11.975	0.321	
	0.418	0.513	2.315	11.674	11.436	0.349	
Avg	0.416	0.518	2.269	11.949	11.719	0.324	
cov	0.6%	5.7%	1.8%	2.0%	2.3%	7.2%	
Nonroad High Sulfur Diesel (EM-2664-F)							
	0.420	0.405	2.107	12.216	11.961	0.356	
	0.419	0.540	2.160	12.478	12.263	0.368	
	0.419	0.530	2.108	12.577	12.347	0.382	
Avg	0.419	0.492	2.125	12.424	12.190	0.369	
cov	0.2%	15.3%	1.4%	1.5%	1.7%	3.7%	
	-1.7%	8%	8%	-6%	-5%	-11%	carb vs HS
	-0.9%	5%	7%	-4%	-4%	-12%	on-hwy vs HS
	-0.8%	3%	1%	-2%	-2%	2%	carb vs on-hwy

Note: EPA NOx = full NOx correction factor
Note: KH NOx = only ambient air humidity NOx correction factor applied

APPENDIX A-2

BNSF No. 9693 Test Results Using CARB Diesel Fuel

BNSF #9693 Test Date 09-17-98 CARB Diesel Fuel EM-2663-F Run #1/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	19	46.5	122	284	1,086	1,064	33
Low Idle	14	24.0	109	137	687	674	15
Idle	19	46.5	122	284	1,086	1,064	33
N1	205	88.8	193	312	2,109	2,069	54
N2	438	169.2	250	415	4,377	4,300	106
N3	980	352.8	370	549	9,850	9,691	243
N4	1,519	535.2	432	1,518	16,850	16,574	387
N5	2,005	702.0	549	4,437	21,813	21,428	538
N6	2,881	994.0	664	14,924	28,877	28,424	968
N7	3,652	1,215.0	903	11,356	39,624	39,023	1,023
N8	4,208	1,390.8	1,158	9,998	46,128	45,529	2,135
						sum =	6,606

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.4	5.8	15.3	35.5	135.8	133.0	4.1
Low Idle	19.0%	2.6	4.6	20.7	26.0	130.5	128.0	2.9
Idle	19.0%	3.7	8.8	23.2	54.0	206.3	202.2	6.3
N1	6.5%	13.3	5.8	12.5	20.3	137.1	134.5	3.5
N2	6.5%	28.4	11.0	16.3	27.0	284.5	279.5	6.9
N3	5.2%	51.0	18.3	19.2	28.5	512.2	503.9	12.6
N4	4.4%	66.8	23.5	19.0	66.8	741.4	729.3	17.0
N5	3.8%	76.2	26.7	20.9	168.6	828.9	814.3	20.4
N6	3.9%	112.4	38.8	25.9	582.0	1126.2	1108.5	37.8
N7	3.0%	109.6	36.5	27.1	340.7	1188.7	1170.7	30.7
N8	16.2%	681.6	225.3	187.6	1619.7	7472.7	7375.7	345.9
TOTAL	100.0%	1148.0	405.1	387.6	2969.1	12764.4	12579.6	488.1
EPA line-haul duty cycle weighted brake-specific emissions			0.353	0.34	2.6	**11.1**	**11.0**	0.43
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	2.409	6.32	14.72	56.27	55.15	1.71
Low Idle	1.778	8.07	10.15	50.89	49.89	1.11
Idle	2.409	6.32	14.72	56.27	55.15	1.71
N1	0.434	0.94	1.52	10.31	10.11	0.26
N2	0.387	0.57	0.95	10.00	9.83	0.24
N3	0.360	0.38	0.56	10.05	9.89	0.25
N4	0.352	0.28	1.00	11.09	10.91	0.25
N5	0.350	0.27	2.21	10.88	10.69	0.27
N6	0.345	0.23	5.18	10.02	9.87	0.34
N7	0.333	0.25	3.11	10.85	10.68	0.28
N8	0.331	0.28	2.38	10.96	10.82	0.51

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	4.0	7.2	32.6	41.0	205.4	201.4	4.5
Idle	29.9%	5.8	13.9	36.5	84.9	324.7	318.2	9.9
N1	12.4%	25.4	11.0	23.9	38.7	261.5	256.6	6.7
N2	12.3%	53.8	20.8	30.8	51.0	538.4	528.9	13.0
N3	5.8%	56.9	20.5	21.5	31.8	571.3	562.1	14.1
N4	3.6%	54.7	19.3	15.6	54.6	606.6	596.7	13.9
N5	3.6%	72.2	25.3	19.8	159.7	785.3	771.4	19.4
N6	1.5%	43.2	14.9	10.0	223.9	433.2	426.4	14.5
N7	0.2%	7.3	2.4	1.8	22.7	79.2	78.0	2.0
N8	0.8%	33.7	11.1	9.3	80.0	369.0	364.2	17.1
TOTAL	100.0%	356.9	146.4	201.6	788.4	4174.6	4103.9	115.1
EPA switch duty cycle weighted brake-specific emissions			0.410	0.56	2.21	11.70	11.50	0.32
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

BNSF #9693 Test Date 09-22-98 CARB Diesel Fuel EM-2663-F Run #2/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	19	45.5	144	283	1,034	1,012	40
Low Idle	14	24.9	84	151	703	688	14
Idle	19	45.5	144	283	1,034	1,012	40
N1	205	91.2	137	280	2,135	2,094	44
N2	439	172.0	184	377	4,435	4,352	82
N3	980	356.0	276	555	10,333	10,140	230
N4	1,520	539.0	393	1,671	17,184	16,863	388
N5	2,008	709.2	475	4,793	21,698	21,308	540
N6	2,881	1,001.3	748	17,066	30,229	29,747	1,044
N7	3,652	1,222.0	989	14,503	42,073	41,372	1,323
N8	4,230	1,404.9	1,255	11,982	44,464	43,753	2,247
						sum =	

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.4	5.7	18.0	35.4	129.3	126.5	5.0
Low Idle	19.0%	2.6	4.7	16.0	28.7	133.6	130.6	2.7
Idle	19.0%	3.7	8.6	27.4	53.8	196.5	192.2	7.6
N1	6.5%	13.3	5.9	8.9	18.2	138.8	136.1	2.9
N2	6.5%	28.5	11.2	12.0	24.5	288.3	282.9	5.3
N3	5.2%	51.0	18.5	14.4	28.9	537.3	527.3	12.0
N4	4.4%	66.9	23.7	17.3	73.5	756.1	742.0	17.1
N5	3.8%	76.3	26.9	18.1	182.1	824.5	809.7	20.5
N6	3.9%	112.4	39.1	29.2	665.6	1178.9	1160.1	40.7
N7	3.0%	109.6	36.7	29.7	435.1	1262.2	1241.2	39.7
N8	16.2%	685.3	227.6	203.3	1941.1	7203.2	7088.0	364.0
TOTAL	100.0%	1151.9	408.7	394.0	3486.8	12648.6	12436.5	517.4
EPA line-haul duty cycle weighted brake-specific emissions			0.355	0.34	3.0	**11.0**	**10.8**	0.45
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	2.358	7.46	14.66	53.58	52.42	2.07
Low Idle	1.844	6.22	11.19	52.07	50.93	1.04
Idle	2.358	7.46	14.66	53.58	52.42	2.07
N1	0.446	0.67	1.37	10.43	10.24	0.22
N2	0.392	0.42	0.86	10.11	9.92	0.19
N3	0.363	0.28	0.57	10.54	10.35	0.23
N4	0.355	0.26	1.10	11.31	11.09	0.26
N5	0.353	0.24	2.39	10.81	10.61	0.27
N6	0.348	0.26	5.92	10.49	10.32	0.36
N7	0.335	0.27	3.97	11.52	11.33	0.36
N8	0.332	0.30	2.83	10.51	10.34	0.53

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	4.0	7.4	25.1	45.1	210.2	205.6	4.2
Idle	29.9%	5.8	13.6	43.1	84.6	309.2	302.5	12.0
N1	12.4%	25.4	11.3	17.0	34.7	264.7	259.7	5.5
N2	12.3%	54.0	21.2	22.6	46.4	545.5	535.3	10.1
N3	5.8%	56.8	20.6	16.0	32.2	599.3	588.1	13.3
N4	3.6%	54.7	19.4	14.1	60.2	618.6	607.1	14.0
N5	3.6%	72.3	25.5	17.1	172.5	781.1	767.1	19.4
N6	1.5%	43.2	15.0	11.2	256.0	453.4	446.2	15.7
N7	0.2%	7.3	2.4	2.0	29.0	84.1	82.7	2.6
N8	0.8%	33.8	11.2	10.0	95.9	355.7	350.0	18.0
TOTAL	100.0%	357.4	147.8	178.3	856.6	4222.0	4144.2	114.7
EPA switch duty cycle weighted brake-specific emissions			0.414	0.50	2.40	11.81	11.60	0.32
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

BNSF #9693 Test Date 09-25-98 CARB Diesel Fuel EM-2663-F Run #3/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	19	46.9	167	273	1,062	1,046	50
Low Idle	14	24.5	94	158	714	704	18
Idle	19	46.9	167	273	1,062	1,046	50
N1	205	90.6	147	303	2,068	2,039	65
N2	438	170.4	208	386	4,484	4,429	113
N3	980	354.5	289	572	10,270	10,130	277
N4	1,519	537.0	386	1,597	16,292	16,094	409
N5	2,006	706.5	484	4,442	21,368	21,123	543
N6	2,882	998.4	610	15,906	29,343	28,683	837
N7	3,655	1,216.8	854	12,889	42,725	41,570	1,050
N8	4,211	1,392.2	1,084	10,948	44,628	43,506	2,024
						sum =	

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.4	5.9	20.9	34.1	132.8	130.7	6.3
Low Idle	19.0%	2.6	4.7	17.9	30.0	135.7	133.8	3.4
Idle	19.0%	3.7	8.9	31.7	51.9	201.8	198.7	9.5
N1	6.5%	13.3	5.9	9.6	19.7	134.4	132.5	4.2
N2	6.5%	28.4	11.1	13.5	25.1	291.5	287.9	7.3
N3	5.2%	51.0	18.4	15.0	29.7	534.0	526.8	14.4
N4	4.4%	66.8	23.6	17.0	70.3	716.8	708.1	18.0
N5	3.8%	76.2	26.8	18.4	168.8	812.0	802.7	20.6
N6	3.9%	112.4	38.9	23.8	620.3	1144.4	1118.6	32.6
N7	3.0%	109.6	36.5	25.6	386.7	1281.8	1247.1	31.5
N8	16.2%	682.2	225.5	175.6	1773.6	7229.7	7048.0	327.9
TOTAL	100.0%	1148.6	406.3	369.0	3210.2	12614.8	12335.0	475.8
EPA line-haul duty cycle weighted brake-specific emissions			0.354	0.32	2.8	**11.0**	**10.7**	0.41
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	2.430	8.65	14.15	55.03	54.18	2.59
Low Idle	1.815	6.96	11.70	52.89	52.17	1.33
Idle	2.430	8.65	14.15	55.03	54.18	2.59
N1	0.443	0.72	1.48	10.10	9.96	0.32
N2	0.389	0.48	0.88	10.25	10.12	0.26
N3	0.362	0.29	0.58	10.48	10.34	0.28
N4	0.354	0.25	1.05	10.73	10.60	0.27
N5	0.352	0.24	2.21	10.65	10.53	0.27
N6	0.346	0.21	5.52	10.18	9.95	0.29
N7	0.333	0.23	3.53	11.69	11.37	0.29
N8	0.331	0.26	2.60	10.60	10.33	0.48

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	4.0	7.3	28.1	47.2	213.5	210.6	5.4
Idle	29.9%	5.8	14.0	49.9	81.6	317.5	312.6	15.0
N1	12.4%	25.4	11.2	18.2	37.6	256.4	252.8	8.1
N2	12.3%	53.8	21.0	25.6	47.5	551.5	544.8	13.9
N3	5.8%	56.9	20.6	16.8	33.2	595.7	587.6	16.1
N4	3.6%	54.7	19.3	13.9	57.5	586.5	579.4	14.7
N5	3.6%	72.2	25.4	17.4	159.9	769.2	760.4	19.5
N6	1.5%	43.2	15.0	9.2	238.6	440.1	430.2	12.6
N7	0.2%	7.3	2.4	1.7	25.8	85.5	83.1	2.1
N8	0.8%	33.7	11.1	8.7	87.6	357.0	348.1	16.2
TOTAL	100.0%	357.0	147.4	189.5	816.5	4173.0	4109.7	123.5
EPA switch duty cycle weighted brake-specific emissions			0.413	0.53	2.29	11.69	11.51	0.35
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

APPENDIX A-3

BNSF No. 9693 Test Results Using On-Highway Diesel Fuel

BNSF #9693 Test Date 09-16-98 On-Highway Fuel EM-2677-F Run #1/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	19	46.6	181	364	1,115	1,085	31
Low Idle	14	26.5	108	204	795	774	17
Idle	19	46.6	181	364	1,115	1,085	31
N1	205	92.4	155	374	2,255	2,193	50
N2	437	170.9	199	444	4,405	4,298	90
N3	980	354.5	308	594	10,220	9,954	216
N4	1,519	538.5	382	1,495	17,243	16,828	356
N5	2,005	706.8	450	3,980	21,325	20,828	502
N6	2,881	993.6	579	13,416	30,745	30,005	890
N7	3,655	1,214.4	841	9,893	43,803	42,767	1,119
N8	4,210	1,393.2	1,001	9,916	46,932	45,821	2,184
							sum =

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.4	5.8	22.6	45.5	139.4	135.7	3.9
Low Idle	19.0%	2.6	5.0	20.5	38.8	151.1	147.0	3.2
Idle	19.0%	3.7	8.9	34.4	69.2	211.9	206.2	5.9
N1	6.5%	13.3	6.0	10.1	24.3	146.6	142.5	3.3
N2	6.5%	28.4	11.1	12.9	28.9	286.3	279.4	5.9
N3	5.2%	50.9	18.4	16.0	30.9	531.4	517.6	11.2
N4	4.4%	66.8	23.7	16.8	65.8	758.7	740.4	15.7
N5	3.8%	76.2	26.9	17.1	151.2	810.4	791.5	19.1
N6	3.9%	112.4	38.8	22.6	523.2	1199.1	1170.2	34.7
N7	3.0%	109.7	36.4	25.2	296.8	1314.1	1283.0	33.6
N8	16.2%	682.0	225.7	162.2	1606.4	7603.0	7423.0	353.8
TOTAL	100.0%	1148.4	406.7	360.4	2880.9	13151.8	12836.6	490.2
EPA line-haul duty cycle weighted brake-specific emissions			0.354	0.31	2.5	**11.5**	**11.2**	0.43
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	2.402	9.33	18.76	57.47	55.94	1.60
Low Idle	1.963	8.00	15.11	58.89	57.31	1.26
Idle	2.402	9.33	18.76	57.47	55.94	1.60
N1	0.452	0.76	1.83	11.02	10.72	0.24
N2	0.391	0.45	1.02	10.07	9.83	0.21
N3	0.362	0.31	0.61	10.43	10.16	0.22
N4	0.355	0.25	0.98	11.35	11.08	0.23
N5	0.353	0.22	1.99	10.64	10.39	0.25
N6	0.345	0.20	4.66	10.67	10.41	0.31
N7	0.332	0.23	2.71	11.98	11.70	0.31
N8	0.331	0.24	2.36	11.15	10.88	0.52

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	4.0	7.9	32.3	61.0	237.7	231.3	5.1
Idle	29.9%	5.8	13.9	54.1	108.8	333.4	324.5	9.3
N1	12.4%	25.4	11.5	19.2	46.4	279.6	271.9	6.2
N2	12.3%	53.8	21.0	24.5	54.6	541.8	528.7	11.1
N3	5.8%	56.8	20.6	17.9	34.5	592.8	577.4	12.5
N4	3.6%	54.7	19.4	13.8	53.8	620.7	605.8	12.8
N5	3.6%	72.2	25.4	16.2	143.3	767.7	749.8	18.1
N6	1.5%	43.2	14.9	8.7	201.2	461.2	450.1	13.4
N7	0.2%	7.3	2.4	1.7	19.8	87.6	85.5	2.2
N8	0.8%	33.7	11.1	8.0	79.3	375.5	366.6	17.5
TOTAL	100.0%	356.9	148.2	196.3	802.7	4298.0	4191.6	108.1
EPA switch duty cycle weighted brake-specific emissions			0.415	0.55	2.25	12.04	11.75	0.30
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

BNSF #9693 Test Date 09-18-98 On-Highway Fuel EM-2677-F Run #2/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	19	45.5	133	311	1,109	1,091	48
Low Idle	14	24.8	91	172	784	769	14
Idle	19	45.5	133	311	1,109	1,091	48
N1	205	90.0	135	268	2,223	2,187	44
N2	439	171.6	200	424	4,551	4,494	97
N3	980	356.0	281	585	10,121	9,998	232
N4	1,519	544.0	362	1,559	17,585	17,381	373
N5	2,005	705.6	475	4,139	21,949	21,692	518
N6	2,881	1,002.8	674	15,066	30,356	30,055	954
N7	3,654	1,220.4	886	11,708	43,465	42,997	1,074
N8	4,206	1,396.8	1,137	10,270	46,948	46,422	2,101
						sum =	

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.4	5.7	16.6	38.9	138.6	136.3	6.0
Low Idle	19.0%	2.6	4.7	17.3	32.7	149.0	146.2	2.7
Idle	19.0%	3.7	8.6	25.3	59.1	210.7	207.2	9.1
N1	6.5%	13.3	5.9	8.8	17.4	144.5	142.1	2.9
N2	6.5%	28.5	11.2	13.0	27.6	295.8	292.1	6.3
N3	5.2%	51.0	18.5	14.6	30.4	526.3	519.9	12.1
N4	4.4%	66.8	23.9	15.9	68.6	773.7	764.8	16.4
N5	3.8%	76.2	26.8	18.1	157.3	834.1	824.3	19.7
N6	3.9%	112.3	39.1	26.3	587.6	1183.9	1172.2	37.2
N7	3.0%	109.6	36.6	26.6	351.2	1304.0	1289.9	32.2
N8	16.2%	681.4	226.3	184.2	1663.7	7605.6	7520.4	340.4
TOTAL	100.0%	1147.8	407.3	366.6	3034.5	13166.1	13015.4	484.9
EPA line-haul duty cycle weighted brake-specific emissions			0.355	0.319	2.644	11.471	11.340	0.422
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	2.358	6.89	16.11	57.46	56.51	2.49
Low Idle	1.837	6.74	12.74	58.07	56.99	1.04
Idle	2.358	6.89	16.11	57.46	56.51	2.49
N1	0.440	0.66	1.31	10.87	10.69	0.22
N2	0.391	0.46	0.97	10.38	10.25	0.22
N3	0.363	0.29	0.60	10.33	10.20	0.24
N4	0.358	0.24	1.03	11.58	11.45	0.25
N5	0.352	0.24	2.06	10.95	10.82	0.26
N6	0.348	0.23	5.23	10.54	10.43	0.33
N7	0.334	0.24	3.20	11.89	11.77	0.29
N8	0.332	0.27	2.44	11.16	11.04	0.50

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	4.0	7.4	27.2	51.4	234.4	230.0	4.2
Idle	29.9%	5.8	13.6	39.8	93.0	331.6	326.1	14.4
N1	12.4%	25.4	11.2	16.7	33.2	275.7	271.2	5.5
N2	12.3%	53.9	21.1	24.6	52.2	559.8	552.7	11.9
N3	5.8%	56.8	20.6	16.3	33.9	587.0	579.9	13.5
N4	3.6%	54.7	19.6	13.0	56.1	633.1	625.7	13.4
N5	3.6%	72.2	25.4	17.1	149.0	790.2	780.9	18.6
N6	1.5%	43.2	15.0	10.1	226.0	455.3	450.8	14.3
N7	0.2%	7.3	2.4	1.8	23.4	86.9	86.0	2.1
N8	0.8%	33.6	11.2	9.1	82.2	375.6	371.4	16.8
TOTAL	100.0%	357.0	147.6	175.7	800.4	4329.5	4274.7	114.7
EPA switch duty cycle weighted brake-specific emissions			0.413	0.492	2.242	12.129	11.975	0.321
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

BNSF #9693 Test Date 09-23-98, 09-24-98 On-Highway Fuel EM-2677-F Run #3/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	19	48.0	148	312	1,113	1,089	48
Low Idle	14	26.0	86	170	746	731	42
Idle	19	48.0	148	312	1,113	1,089	48
N1	205	91.8	144	345	2,208	2,161	57
N2	439	172.3	195	448	4,537	4,439	100
N3	980	358.5	297	556	9,931	9,738	217
N4	1,520	542.6	385	1,485	14,426	14,087	363
N5	2,008	711.3	497	4,281	21,829	21,406	525
N6	2,891	1,007.1	711	15,980	30,060	29,490	1,011
N7	3,652	1,225.5	969	12,396	42,737	41,916	1,094
N8	4,208	1,403.1	1,223	10,098	45,781	44,930	2,074
							sum =

Weighted Results

Notch	EPA Line-Haul WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.4	6.0	18.5	39.0	139.1	136.2	6.0
Low Idle	19.0%	2.6	4.9	16.3	32.3	141.7	138.8	8.0
Idle	19.0%	3.7	9.1	28.1	59.3	211.5	207.0	9.1
N1	6.5%	13.3	6.0	9.4	22.4	143.5	140.5	3.7
N2	6.5%	28.5	11.2	12.7	29.1	294.9	288.6	6.5
N3	5.2%	51.0	18.6	15.4	28.9	516.4	506.4	11.3
N4	4.4%	66.9	23.9	16.9	65.3	634.7	619.8	16.0
N5	3.8%	76.3	27.0	18.9	162.7	829.5	813.4	20.0
N6	3.9%	112.7	39.3	27.7	623.2	1172.3	1150.1	39.4
N7	3.0%	109.6	36.8	29.1	371.9	1282.1	1257.5	32.8
N8	16.2%	681.7	227.3	198.1	1635.9	7416.5	7278.7	336.0
TOTAL	100.0%	1148.6	410.1	391.2	3070.0	12782.4	12536.9	488.7
EPA line-haul duty cycle weighted brake-specific emissions			0.357	0.34	2.7	**11.1**	**10.9**	0.43
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	2.487	7.67	16.17	57.67	56.45	2.49
Low Idle	1.926	6.37	12.59	55.26	54.12	3.11
Idle	2.487	7.67	16.17	57.67	56.45	2.49
N1	0.449	0.70	1.69	10.79	10.56	0.28
N2	0.393	0.44	1.02	10.35	10.12	0.23
N3	0.366	0.30	0.57	10.13	9.93	0.22
N4	0.357	0.25	0.98	9.49	9.27	0.24
N5	0.354	0.25	2.13	10.87	10.66	0.26
N6	0.348	0.25	5.53	10.40	10.20	0.35
N7	0.336	0.27	3.39	11.70	11.48	0.30
N8	0.333	0.29	2.40	10.88	10.68	0.49

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	4.0	7.8	25.7	50.8	223.1	218.5	12.6
Idle	29.9%	5.8	14.4	44.3	93.3	332.8	325.7	14.4
N1	12.4%	25.4	11.4	17.9	42.8	273.8	268.0	7.1
N2	12.3%	53.9	21.2	24.0	55.1	558.1	546.0	12.3
N3	5.8%	56.9	20.8	17.2	32.2	576.0	564.8	12.6
N4	3.6%	54.7	19.5	13.9	53.5	519.3	507.1	13.1
N5	3.6%	72.3	25.6	17.9	154.1	785.8	770.6	18.9
N6	1.5%	43.4	15.1	10.7	239.7	450.9	442.4	15.2
N7	0.2%	7.3	2.5	1.9	24.8	85.5	83.8	2.2
N8	0.8%	33.7	11.2	9.8	80.8	366.2	359.4	16.6
TOTAL	100.0%	357.3	149.4	183.2	827.1	4171.5	4086.4	124.8
EPA switch duty cycle weighted brake-specific emissions			0.418	0.51	2.31	11.67	11.44	0.35
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

APPENDIX A-4

BNSF No. 9693 Test Results Using High-Sulfur Diesel Fuel

BNSF #9693 Test Date 09-17-98 Nonroad High-Sulfur Diesel Fuel EM-2664-F Run #1/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	19	49.4	125	337	1,172	1,146	35
Low Idle	14	25.2	70	168	748	731	17
Idle	19	49.4	125	337	1,172	1,146	35
N1	206	92.4	116	321	2,261	2,213	49
N2	439	174.9	166	433	4,628	4,532	100
N3	979	360.0	238	492	10,216	9,998	264
N4	1,519	544.0	296	1,338	17,615	17,243	452
N5	2,007	714.0	348	3,782	21,885	21,430	660
N6	2,884	1,005.6	495	13,475	30,833	30,202	1,118
N7	3,655	1,220.4	618	10,329	42,912	42,051	1,228
N8	4,209	1,398.0	761	9,123	47,229	46,343	2,318
						sum =	

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.4	6.2	15.6	42.1	146.5	143.3	4.4
Low Idle	19.0%	2.6	4.8	13.3	31.9	142.1	138.9	3.2
Idle	19.0%	3.7	9.4	23.8	64.0	222.7	217.8	6.7
N1	6.5%	13.4	6.0	7.5	20.9	147.0	143.8	3.2
N2	6.5%	28.5	11.4	10.8	28.1	300.8	294.6	6.5
N3	5.2%	50.9	18.7	12.4	25.6	531.2	519.9	13.7
N4	4.4%	66.8	23.9	13.0	58.9	775.1	758.7	19.9
N5	3.8%	76.3	27.1	13.2	143.7	831.6	814.3	25.1
N6	3.9%	112.5	39.2	19.3	525.5	1202.5	1177.9	43.6
N7	3.0%	109.7	36.6	18.5	309.9	1287.4	1261.5	36.8
N8	16.2%	681.8	226.5	123.3	1477.9	7651.1	7507.6	375.5
TOTAL	100.0%	1148.5	409.8	270.8	2728.6	13238.0	12978.3	538.6
EPA line-haul duty cycle weighted brake-specific emissions			0.357	0.24	2.4	**11.5**	**11.3**	0.47
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	2.546	6.44	17.37	60.41	59.08	1.80
Low Idle	1.867	5.19	12.44	55.41	54.17	1.26
Idle	2.546	6.44	17.37	60.41	59.08	1.80
N1	0.449	0.56	1.56	11.00	10.76	0.24
N2	0.399	0.38	0.99	10.55	10.33	0.23
N3	0.368	0.24	0.50	10.43	10.21	0.27
N4	0.358	0.19	0.88	11.59	11.35	0.30
N5	0.356	0.17	1.88	10.91	10.68	0.33
N6	0.349	0.17	4.67	10.69	10.47	0.39
N7	0.334	0.17	2.83	11.74	11.50	0.34
N8	0.332	0.18	2.17	11.22	11.01	0.55

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	4.0	7.5	20.9	50.2	223.7	218.6	5.1
Idle	29.9%	5.8	14.8	37.4	100.8	350.4	342.7	10.5
N1	12.4%	25.5	11.5	14.4	39.8	280.4	274.4	6.1
N2	12.3%	53.9	21.5	20.4	53.3	569.2	557.4	12.3
N3	5.8%	56.8	20.9	13.8	28.5	592.5	579.9	15.3
N4	3.6%	54.7	19.6	10.7	48.2	634.1	620.7	16.3
N5	3.6%	72.2	25.7	12.5	136.2	787.9	771.5	23.8
N6	1.5%	43.3	15.1	7.4	202.1	462.5	453.0	16.8
N7	0.2%	7.3	2.4	1.2	20.7	85.8	84.1	2.5
N8	0.8%	33.7	11.2	6.1	73.0	377.8	370.7	18.5
TOTAL	100.0%	357.3	150.2	144.8	752.7	4364.4	4273.1	127.0
EPA switch duty cycle weighted brake-specific emissions			0.420	0.41	2.11	12.22	11.96	0.36
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

BNSF #9693 Test Date 09-18-98 Nonroad High-Sulfur Diesel Fuel EM-2664-F Run #2/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	19	48.0	165	312	1,167	1,146	35
Low Idle	14	25.5	95	164	767	751	14
Idle	19	48.0	165	312	1,167	1,146	35
N1	205	92.0	143	319	2,279	2,240	52
N2	439	174.0	203	407	4,631	4,553	114
N3	980	360.0	318	559	10,483	10,300	311
N4	1,519	544.0	381	1,408	17,368	17,089	436
N5	2,007	714.0	472	3,868	22,014	21,621	639
N6	2,884	1,002.0	791	15,023	34,912	34,344	1,022
N7	3,655	1,217.0	935	9,973	43,441	42,694	1,246
N8	4,209	1,394.4	1,203	9,003	48,761	47,940	2,699
							sum =

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.4	6.0	20.6	39.0	145.9	143.3	4.4
Low Idle	19.0%	2.6	4.8	18.1	31.2	145.7	142.8	2.7
Idle	19.0%	3.7	9.1	31.4	59.3	221.7	217.8	6.7
N1	6.5%	13.3	6.0	9.3	20.7	148.1	145.6	3.4
N2	6.5%	28.5	11.3	13.2	26.5	301.0	295.9	7.4
N3	5.2%	51.0	18.7	16.5	29.1	545.1	535.6	16.2
N4	4.4%	66.8	23.9	16.8	62.0	764.2	751.9	19.2
N5	3.8%	76.2	27.1	17.9	147.0	836.5	821.6	24.3
N6	3.9%	112.5	39.1	30.8	585.9	1361.6	1339.4	39.9
N7	3.0%	109.7	36.5	28.1	299.2	1303.2	1280.8	37.4
N8	16.2%	681.8	225.9	194.9	1458.5	7899.3	7766.3	437.2
TOTAL	100.0%	1148.5	408.5	397.5	2758.2	13672.4	13441.0	598.6
EPA line-haul duty cycle weighted brake-specific emissions			0.356	0.35	2.4	**11.9**	**11.7**	0.52
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

EPA Switch Cycle

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	2.474	8.51	16.08	60.15	59.08	1.80
Low Idle	1.889	7.04	12.15	56.81	55.66	1.04
Idle	2.474	8.51	16.08	60.15	59.08	1.80
N1	0.450	0.70	1.56	11.14	10.95	0.25
N2	0.397	0.46	0.93	10.56	10.38	0.26
N3	0.367	0.32	0.57	10.69	10.51	0.32
N4	0.358	0.25	0.93	11.43	11.25	0.29
N5	0.356	0.24	1.93	10.97	10.78	0.32
N6	0.347	0.27	5.21	12.11	11.91	0.35
N7	0.333	0.26	2.73	11.88	11.68	0.34
N8	0.331	0.29	2.14	11.59	11.39	0.64

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	4.0	7.6	28.4	49.0	229.3	224.7	4.2
Idle	29.9%	5.8	14.4	49.3	93.3	348.9	342.7	10.5
N1	12.4%	25.4	11.4	17.7	39.6	282.6	277.7	6.4
N2	12.3%	53.9	21.4	25.0	50.1	569.6	560.0	14.0
N3	5.8%	56.9	20.9	18.4	32.4	608.0	597.4	18.0
N4	3.6%	54.7	19.6	13.7	50.7	625.2	615.2	15.7
N5	3.6%	72.2	25.7	17.0	139.2	792.5	778.3	23.0
N6	1.5%	43.3	15.0	11.9	225.3	523.7	515.2	15.3
N7	0.2%	7.3	2.4	1.9	19.9	86.9	85.4	2.5
N8	0.8%	33.7	11.2	9.6	72.0	390.1	383.5	21.6
TOTAL	100.0%	357.2	149.6	193.0	771.6	4456.9	4380.1	131.3
EPA switch duty cycle weighted brake-specific emissions			0.419	0.54	2.16	12.48	12.26	0.37
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

BNSF #9693 Test Date 09-24-98, 09-25-98 Nonroad High-Sulfur Diesel Fuel EM-2664-F Run #3/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	19	47.5	153	335	1,457	1,431	55
Low Idle	14	25.2	93	168	764	750	17
Idle	19	47.5	153	335	1,457	1,431	55
N1	205	93.0	144	332	2,343	2,311	50
N2	438	174.0	199	453	4,588	4,518	100
N3	980	361.0	295	566	10,371	10,234	287
N4	1,519	543.6	396	1,466	17,648	17,251	456
N5	2,008	713.3	510	3,646	21,813	21,338	657
N6	2,882	1,003.2	726	13,153	31,314	30,656	1,141
N7	3,656	1,221.4	986	9,799	43,742	42,964	1,478
N8	4,209	1,400.0	1,354	8,967	49,064	48,209	2,469
							sum =

Weighted Results

Notch	EPA Line-Haul WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.4	5.9	19.1	41.9	182.1	178.8	6.9
Low Idle	19.0%	2.6	4.8	17.7	31.9	145.2	142.6	3.2
Idle	19.0%	3.7	9.0	29.1	63.7	276.8	271.8	10.5
N1	6.5%	13.3	6.0	9.4	21.6	152.3	150.2	3.3
N2	6.5%	28.5	11.3	12.9	29.4	298.2	293.6	6.5
N3	5.2%	51.0	18.8	15.3	29.4	539.3	532.2	14.9
N4	4.4%	66.9	23.9	17.4	64.5	776.5	759.1	20.1
N5	3.8%	76.3	27.1	19.4	138.5	828.9	810.9	25.0
N6	3.9%	112.4	39.1	28.3	513.0	1221.2	1195.6	44.5
N7	3.0%	109.7	36.6	29.6	294.0	1312.3	1288.9	44.3
N8	16.2%	681.9	226.8	219.3	1452.7	7948.4	7809.8	400.0
TOTAL	100.0%	1148.4	409.5	417.5	2680.5	13681.2	13433.5	579.1

EPA line-haul duty cycle weighted brake-specific emissions	0.357	0.36	2.3	**11.9**	**11.7**	0.50
EPA line-haul duty cycle maximum Tier 0		1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	2.461	7.93	17.36	75.49	74.12	2.85
Low Idle	1.867	6.89	12.44	56.59	55.59	1.26
Idle	2.461	7.93	17.36	75.49	74.12	2.85
N1	0.454	0.70	1.62	11.45	11.29	0.24
N2	0.398	0.45	1.03	10.48	10.32	0.23
N3	0.368	0.30	0.58	10.58	10.44	0.29
N4	0.358	0.26	0.96	11.62	11.35	0.30
N5	0.355	0.25	1.82	10.86	10.63	0.33
N6	0.348	0.25	4.56	10.87	10.64	0.40
N7	0.334	0.27	2.68	11.97	11.75	0.40
N8	0.333	0.32	2.13	11.66	11.45	0.59

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	4.0	7.5	27.8	50.2	228.4	224.4	5.1
Idle	29.9%	5.8	14.2	45.7	100.2	435.6	427.8	16.4
N1	12.4%	25.4	11.5	17.9	41.2	290.5	286.5	6.2
N2	12.3%	53.8	21.4	24.5	55.7	564.3	555.7	12.3
N3	5.8%	56.8	20.9	17.1	32.8	601.5	593.6	16.6
N4	3.6%	54.7	19.6	14.3	52.8	635.3	621.0	16.4
N5	3.6%	72.3	25.7	18.4	131.3	785.3	768.2	23.7
N6	1.5%	43.2	15.0	10.9	197.3	469.7	459.8	17.1
N7	0.2%	7.3	2.4	2.0	19.6	87.5	85.9	3.0
N8	0.8%	33.7	11.2	10.8	71.7	392.5	385.7	19.8
TOTAL	100.0%	357.1	149.5	189.3	752.8	4490.8	4408.6	136.6

EPA switch duty cycle weighted brake-specific emissions	0.419	0.53	2.11	12.58	12.35	0.38
EPA switch cycle maximum Tier 0		2.10	8.0	14.0	14.0	0.72

APPENDIX A-5

BNSF No. 9693 Smoke Test Summary

SMOKE TEST SUMMARY FOR BNSF NO. 9693

Run #	**ss**	**30-sec**	**3-sec**
Carb Diesel (EM-2663-F)			
# 1	17	25	28
# 2	21	24	26
# 3	19	26	29
Avg	**19**	**25**	**28**
cov	11%	4%	6%
On-Highway Diesel (EM-2677-F)			
# 1	11	19	26
# 2	19	23	26
# 3	17	23	28
Avg	**16**	**22**	**27**
cov	27%	11%	4%
Nonroad High Sulfur Diesel (EM-2664-F)			
# 1	11	21	25
# 2	15	20	25
# 3	14	19	23
Avg	**13**	**20**	**24**
cov	16%	5%	5%

updated 10/19/98 sgf

APPENDIX B-1

BNSF No. 9754 Test Summary

EPA Line-Haul Duty Cycle Weighting Factors

	obs bsfc	HC	CO	EPA NOx	KH-NOx	PM	BNSF 9754 EMD SD70MAC updated 06-29-99
	lb/hp-hr	g/hp-hr	g/hp-hr	g/hp-hr	g/hp-hr	g/hp-hr	
Carb Diesel (EM-2663-F)							
	0.349	0.32	2.6	11.728	11.481	0.34	
	0.345	0.32	1.8	11.912	11.849	0.34	
	0.346	0.31	1.7	11.785	11.609	0.38	
Avg	**0.347**	**0.317**	**2.04**	**11.808**	**11.646**	**0.356**	
cov	0.5%	1.3%	23.7%	0.8%	1.6%	6.7%	
On-Highway Diesel (EM-2677-F)							
	0.346	0.30	1.5	12.301	12.275	0.35	
	0.348	0.28	1.8	12.132	12.028	0.33	
	0.348	0.31	1.8	12.174	12.107	0.38	
	0.349	0.31	2.0	12.111	12.012	0.35	
Avg	**0.348**	**0.303**	**1.80**	**12.179**	**12.106**	**0.353**	
cov	0.4%	5.5%	11.1%	0.7%	1.0%	6.0%	
Nonroad High Sulfur Diesel (EM-2664-F)							
	0.354	0.29	2.4	12.277	12.072	0.37	
	0.350	0.32	1.6	12.096	11.995	0.41	
	0.351	0.31	1.9	12.458	12.274	0.40	
	0.351	0.35	1.9	12.440	12.299	0.43	
Avg	**0.351**	**0.318**	**1.95**	**12.318**	**12.160**	**0.404**	
cov	0.5%	7.1%	16.5%	1.4%	1.2%	6.6%	
	-1.3%	-0%	5%	-4%	-4%	-12%	carb vs HS
	-1.0%	-5%	-7%	-1%	-0%	-13%	on-hwy vs HS
	-0.3%	5%	14%	-3%	-4%	1%	carb vs on-hwy

EPA Switcher Duty Cycle Weighting Factors

	obs bsfc	HC	CO	EPA NOx	KH-NOx	PM	
	lb/hp-hr	g/hp-hr	g/hp-hr	g/hp-hr	g/hp-hr	g/hp-hr	
Carb Diesel (EM-2663-F)							
	0.414	0.49	2.06	12.012	11.764	0.35	
	0.410	0.53	1.67	12.173	12.117	0.33	
	0.411	0.52	1.54	12.279	12.098	0.41	
Avg	**0.412**	**0.512**	**1.76**	**12.155**	**11.993**	**0.360**	
cov	0.6%	4.5%	15.4%	1.1%	1.7%	11.2%	
On-Highway Diesel (EM-2677-F)							
	0.413	0.50	1.52	12.493	12.476	0.34	
	0.411	0.43	1.62	12.473	12.370	0.34	
	0.413	0.52	1.73	12.437	12.366	0.37	
	0.412	0.52	1.77	12.552	12.442	0.34	
Avg	**0.412**	**0.493**	**1.66**	**12.489**	**12.413**	**0.347**	
cov	0.2%	8.5%	6.8%	0.4%	0.4%	4.6%	
Nonroad High Sulfur Diesel (EM-2664-F)							
	0.420	0.48	1.88	12.588	12.369	0.39	
	0.417	0.54	1.57	12.535	12.428	0.41	
	0.418	0.50	1.77	12.635	12.431	0.39	
	0.417	0.57	1.88	12.601	12.442	0.44	
Avg	**0.418**	**0.521**	**1.77**	**12.590**	**12.417**	**0.407**	
cov	0.3%	7.4%	8.2%	0.3%	0.3%	5.1%	
	-1.5%	-2%	-1%	-3%	-3%	-12%	carb vs HS
	-1.4%	-5%	-7%	-1%	-0%	-15%	on-hwy vs HS
	-0.1%	4%	6%	-3%	-3%	4%	carb vs on-hwy

APPENDIX B-2

BNSF No. 9754 Test Results Using CARB Diesel Fuel

BNSF #9754 Test Date 10-5-98 CARB Diesel Fuel EM-2663-F Run #1/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	19	47.4	135	268	1,136	1,108	52
Low Idle	14	28.2	74	116	735	717	20
Idle	19	47.4	135	268	1,136	1,108	52
N1	205	92.4	137	290	2,226	2,178	58
N2	438	171.0	184	421	4,534	4,443	101
N3	979	353.0	297	570	10,078	9,884	290
N4	1,515	532.0	394	1,511	16,644	16,324	462
N5	2,006	696.0	500	4,064	21,238	20,813	567
N6	2,880	978.0	758	12,787	30,818	30,203	958
N7	3,653	1,190.4	962	10,229	44,010	43,103	1,185
N8	4,208	1,363.2	1,094	10,967	48,998	47,943	1,447
						sum =	

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.4	5.9	16.9	33.5	142.0	138.6	6.5
Low Idle	19.0%	2.6	5.4	14.1	22.0	139.7	136.2	3.8
Idle	19.0%	3.6	9.0	25.7	50.9	215.8	210.6	9.9
N1	6.5%	13.3	6.0	8.9	18.9	144.7	141.6	3.8
N2	6.5%	28.4	11.1	12.0	27.4	294.7	288.8	6.6
N3	5.2%	50.9	18.4	15.4	29.6	524.1	514.0	15.1
N4	4.4%	66.7	23.4	17.3	66.5	732.3	718.2	20.3
N5	3.8%	76.2	26.4	19.0	154.4	807.0	790.9	21.5
N6	3.9%	112.3	38.1	29.6	498.7	1201.9	1177.9	37.4
N7	3.0%	109.6	35.7	28.9	306.9	1320.3	1293.1	35.6
N8	16.2%	681.7	220.8	177.2	1776.7	7937.7	7766.8	234.4
TOTAL	100.0%	1147.7	400.3	364.9	2985.4	13460.2	13176.7	394.8
EPA line-haul duty cycle weighted brake-specific emissions			0.349	0.32	2.6	**11.7**	**11.5**	0.34
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	2.495	7.11	14.11	59.79	58.34	2.74
Low Idle	2.089	5.48	8.59	54.44	53.12	1.48
Idle	2.495	7.11	14.11	59.79	58.34	2.74
N1	0.451	0.67	1.42	10.87	10.64	0.28
N2	0.391	0.42	0.96	10.36	10.16	0.23
N3	0.360	0.30	0.58	10.29	10.09	0.30
N4	0.351	0.26	1.00	10.99	10.77	0.30
N5	0.347	0.25	2.03	10.59	10.38	0.28
N6	0.340	0.26	4.44	10.70	10.49	0.33
N7	0.326	0.26	2.80	12.05	11.80	0.32
N8	0.324	0.26	2.61	11.64	11.39	0.34

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	4.0	8.4	22.1	34.7	219.8	214.4	6.0
Idle	29.9%	5.7	14.2	40.4	80.1	339.7	331.4	15.5
N1	12.4%	25.4	11.5	17.0	36.0	276.0	270.1	7.2
N2	12.3%	53.8	21.0	22.6	51.8	557.7	546.5	12.4
N3	5.8%	56.8	20.5	17.2	33.1	584.5	573.3	16.8
N4	3.6%	54.5	19.2	14.2	54.4	599.2	587.7	16.6
N5	3.6%	72.2	25.1	18.0	146.3	764.6	749.3	20.4
N6	1.5%	43.2	14.7	11.4	191.8	462.3	453.0	14.4
N7	0.2%	7.3	2.4	1.9	20.5	88.0	86.2	2.4
N8	0.8%	33.7	10.9	8.8	87.7	392.0	383.5	11.6
TOTAL	100.0%	356.6	147.7	173.6	736.3	4283.7	4195.4	123.3
EPA switch duty cycle weighted brake-specific emissions			0.414	0.49	2.06	12.01	11.76	0.35
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

BNSF #9754 Test Date 10-6-98 CARB Diesel Fuel EM-2663-F Run #2/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	19	46.8	152	312	1,086	1,082	37
Low Idle	14	27.6	89	164	820	818	16
Idle	19	46.8	152	312	1,086	1,082	37
N1	205	91.2	146	306	2,248	2,239	53
N2	438	170.0	205	425	4,532	4,513	103
N3	980	351.0	313	577	10,173	10,124	310
N4	1,515	526.0	404	1,082	16,924	16,843	455
N5	2,002	688.0	551	2,720	21,916	21,811	559
N6	2,881	963.0	770	8,058	30,524	30,357	900
N7	3,651	1,178.0	978	7,008	44,847	44,602	1,201
N8	4,203	1,349.0	1,027	7,195	49,880	49,607	1,460
						sum =	

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.4	5.9	19.0	39.0	135.8	135.2	4.6
Low Idle	19.0%	2.6	5.2	16.9	31.2	155.8	155.4	3.0
Idle	19.0%	3.6	8.9	28.9	59.3	206.3	205.6	7.0
N1	6.5%	13.3	5.9	9.5	19.9	146.1	145.5	3.4
N2	6.5%	28.5	11.1	13.3	27.6	294.6	293.3	6.7
N3	5.2%	50.9	18.3	16.3	30.0	529.0	526.5	16.1
N4	4.4%	66.7	23.1	17.8	47.6	744.7	741.1	20.0
N5	3.8%	76.1	26.1	20.9	103.4	832.8	828.8	21.2
N6	3.9%	112.3	37.6	30.0	314.3	1190.4	1183.9	35.1
N7	3.0%	109.5	35.3	29.3	210.2	1345.4	1338.1	36.0
N8	16.2%	681.0	218.5	166.4	1165.6	8080.6	8036.4	236.5
TOTAL	100.0%	1146.9	395.9	368.3	2048.0	13661.5	13589.8	389.9

EPA line-haul duty cycle weighted brake-specific emissions	0.345	0.32	1.8	**11.9**	**11.8**	0.34
EPA line-haul duty cycle maximum Tier 0		1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	2.450	7.96	16.34	56.86	56.65	1.94
Low Idle	2.044	6.59	12.15	60.74	60.57	1.19
Idle	2.450	7.96	16.34	56.86	56.65	1.94
N1	0.446	0.71	1.50	10.99	10.94	0.26
N2	0.388	0.47	0.97	10.34	10.30	0.23
N3	0.358	0.32	0.59	10.38	10.33	0.32
N4	0.347	0.27	0.71	11.17	11.12	0.30
N5	0.344	0.28	1.36	10.95	10.89	0.28
N6	0.334	0.27	2.80	10.60	10.54	0.31
N7	0.323	0.27	1.92	12.28	12.22	0.33
N8	0.321	0.24	1.71	11.87	11.80	0.35

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	4.0	8.3	26.6	49.0	245.2	244.5	4.8
Idle	29.9%	5.7	14.0	45.4	93.3	324.7	323.5	11.1
N1	12.4%	25.4	11.3	18.1	37.9	278.8	277.6	6.6
N2	12.3%	53.9	20.9	25.2	52.3	557.4	555.1	12.7
N3	5.8%	56.8	20.4	18.2	33.5	590.0	587.2	18.0
N4	3.6%	54.5	18.9	14.5	39.0	609.3	606.3	16.4
N5	3.6%	72.1	24.8	19.8	97.9	789.0	785.2	20.1
N6	1.5%	43.2	14.4	11.6	120.9	457.9	455.4	13.5
N7	0.2%	7.3	2.4	2.0	14.0	89.7	89.2	2.4
N8	0.8%	33.6	10.8	8.2	57.6	399.0	396.9	11.7
TOTAL	100.0%	356.6	146.1	189.6	595.3	4341.0	4320.8	117.2

EPA switch duty cycle weighted brake-specific emissions	0.410	0.53	1.67	12.17	12.12	0.33
EPA switch cycle maximum Tier 0		2.10	8.0	14.0	14.0	0.72

BNSF #9754 Test Date 10-7-98 CARB Diesel Fuel EM-2663-F Run #3/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	20	48.8	145	359	1,152	1,137	67
Low Idle	14	26.8	84	143	792	780	18
Idle	20	48.8	145	359	1,152	1,137	67
N1	205	91.2	142	286	2,253	2,220	91
N2	438	169.8	194	424	4,570	4,504	134
N3	980	351.2	342	355	10,346	10,222	385
N4	1,515	526.4	415	1,014	16,875	16,617	469
N5	2,006	687.7	524	2,075	22,532	22,177	601
N6	2,885	964.8	768	7,359	30,782	30,260	1,017
N7	3,654	1,179.8	981	5,671	44,867	44,130	1,337
N8	4,212	1,354.0	992	7,507	48,748	48,036	1,591
						sum =	

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.4	6.1	18.1	44.9	144.0	142.1	8.4
Low Idle	19.0%	2.6	5.1	16.0	27.2	150.5	148.1	3.4
Idle	19.0%	3.7	9.3	27.6	68.2	218.9	216.1	12.7
N1	6.5%	13.3	5.9	9.2	18.6	146.4	144.3	5.9
N2	6.5%	28.5	11.0	12.6	27.6	297.1	292.8	8.7
N3	5.2%	50.9	18.3	17.8	18.5	538.0	531.5	20.0
N4	4.4%	66.7	23.2	18.3	44.6	742.5	731.2	20.6
N5	3.8%	76.2	26.1	19.9	78.9	856.2	842.7	22.8
N6	3.9%	112.5	37.6	30.0	287.0	1200.5	1180.2	39.7
N7	3.0%	109.6	35.4	29.4	170.1	1346.0	1323.9	40.1
N8	16.2%	682.3	219.3	160.7	1216.1	7897.2	7781.8	257.7
TOTAL	100.0%	1148.7	397.4	359.5	2001.6	13537.2	13334.7	440.2
EPA line-haul duty cycle weighted brake-specific emissions			0.346	0.31	1.7	**11.8**	**11.6**	0.38
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	2.503	7.44	18.41	59.08	58.32	3.44
Low Idle	1.985	6.22	10.59	58.67	57.75	1.33
Idle	2.503	7.44	18.41	59.08	58.32	3.44
N1	0.446	0.69	1.40	11.01	10.85	0.44
N2	0.388	0.44	0.97	10.44	10.29	0.31
N3	0.358	0.35	0.36	10.56	10.43	0.39
N4	0.347	0.27	0.67	11.14	10.97	0.31
N5	0.343	0.26	1.03	11.23	11.06	0.30
N6	0.334	0.27	2.55	10.67	10.49	0.35
N7	0.323	0.27	1.55	12.28	12.08	0.37
N8	0.321	0.24	1.78	11.57	11.41	0.38

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	4.0	8.0	25.1	42.8	236.8	233.1	5.4
Idle	29.9%	5.8	14.6	43.4	107.3	344.4	340.0	20.0
N1	12.4%	25.4	11.3	17.6	35.5	279.4	275.3	11.3
N2	12.3%	53.8	20.9	23.9	52.2	562.1	554.0	16.5
N3	5.8%	56.8	20.4	19.8	20.6	600.1	592.9	22.3
N4	3.6%	54.5	19.0	14.9	36.5	607.5	598.2	16.9
N5	3.6%	72.2	24.8	18.9	74.7	811.2	798.4	21.6
N6	1.5%	43.3	14.5	11.5	110.4	461.7	453.9	15.3
N7	0.2%	7.3	2.4	2.0	11.3	89.7	88.3	2.7
N8	0.8%	33.7	10.8	7.9	60.1	390.0	384.3	12.7
TOTAL	100.0%	356.9	146.5	185.0	551.3	4382.9	4318.4	144.7
EPA switch duty cycle weighted brake-specific emissions			0.411	0.52	1.54	12.28	12.10	0.41
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

APPENDIX B-3

BNSF No. 9754 Test Results Using On-Highway Diesel Fuel

BNSF #9754 Test Date 10-6-98 On-Highway Diesel Fuel EM-2677-F Run #1/4

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	19	47.4	137	308	1,193	1,191	43
Low Idle	14	28.2	86	149	881	880	21
Idle	19	47.4	137	308	1,193	1,191	43
N1	205	94.2	143	314	2,378	2,375	47
N2	438	171.0	189	430	4,464	4,458	103
N3	980	353.0	312	621	10,292	10,285	302
N4	1,515	528.9	374	1,042	17,121	17,095	466
N5	2,005	690.0	509	2,238	22,086	22,054	566
N6	2,883	962.4	736	6,587	32,046	31,996	896
N7	3,655	1,182.0	914	6,223	45,785	45,689	1,287
N8	4,210	1,353.6	968	5,982	51,768	51,639	1,532
						sum =	

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.4	5.9	17.1	38.5	149.1	148.9	5.4
Low Idle	19.0%	2.6	5.4	16.3	28.3	167.4	167.3	4.0
Idle	19.0%	3.6	9.0	26.0	58.5	226.7	226.3	8.2
N1	6.5%	13.3	6.1	9.3	20.4	154.6	154.4	3.1
N2	6.5%	28.5	11.1	12.3	28.0	290.2	289.7	6.7
N3	5.2%	51.0	18.4	16.2	32.3	535.2	534.8	15.7
N4	4.4%	66.7	23.3	16.5	45.8	753.3	752.2	20.5
N5	3.8%	76.2	26.2	19.3	85.0	839.3	838.0	21.5
N6	3.9%	112.4	37.5	28.7	256.9	1249.8	1247.9	34.9
N7	3.0%	109.7	35.5	27.4	186.7	1373.6	1370.7	38.6
N8	16.2%	682.0	219.3	156.8	969.1	8386.4	8365.5	248.2
TOTAL	100.0%	1148.3	397.7	346.0	1749.5	14125.5	14095.7	406.7
EPA line-haul duty cycle weighted brake-specific emissions			0.346	0.30	1.5	**12.3**	**12.3**	0.35
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	2.469	7.14	16.04	62.14	62.04	2.24
Low Idle	2.089	6.37	11.04	65.26	65.22	1.56
Idle	2.469	7.14	16.04	62.14	62.04	2.24
N1	0.460	0.70	1.53	11.62	11.60	0.23
N2	0.390	0.43	0.98	10.18	10.17	0.23
N3	0.360	0.32	0.63	10.50	10.49	0.31
N4	0.349	0.25	0.69	11.30	11.28	0.31
N5	0.344	0.25	1.12	11.02	11.00	0.28
N6	0.334	0.26	2.28	11.12	11.10	0.31
N7	0.323	0.25	1.70	12.53	12.50	0.35
N8	0.322	0.23	1.42	12.30	12.27	0.36

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	4.0	8.4	25.7	44.6	263.4	263.3	6.3
Idle	29.9%	5.7	14.2	41.0	92.1	356.7	356.2	12.9
N1	12.4%	25.4	11.7	17.7	38.9	294.9	294.5	5.8
N2	12.3%	53.9	21.0	23.2	52.9	549.1	548.3	12.7
N3	5.8%	56.8	20.5	18.1	36.0	596.9	596.5	17.5
N4	3.6%	54.6	19.0	13.5	37.5	616.4	615.4	16.8
N5	3.6%	72.2	24.8	18.3	80.6	795.1	793.9	20.4
N6	1.5%	43.2	14.4	11.0	98.8	480.7	479.9	13.4
N7	0.2%	7.3	2.4	1.8	12.4	91.6	91.4	2.6
N8	0.8%	33.7	10.8	7.7	47.9	414.1	413.1	12.3
TOTAL	100.0%	356.9	147.3	178.2	541.7	4458.9	4452.6	120.6
EPA switch duty cycle weighted brake-specific emissions			0.413	0.50	1.52	12.49	12.48	0.34
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

BNSF #9754 Test Date 10-08-98 On-Highway Diesel Fuel EM-2677-F Run #2/4

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	19	46.0	84	212	844	835	48
Low Idle	14	26.6	54	99	609	603	18
Idle	19	46.0	84	212	844	835	48
N1	205	92.4	125	299	2,339	2,317	60
N2	439	171.6	232	528	5,874	5,830	119
N3	980	352.8	318	586	10,545	10,458	315
N4	1,514	531.6	369	1,102	17,525	17,381	451
N5	2,004	692.4	483	2,606	22,022	21,850	552
N6	2,883	974.0	698	9,382	31,314	31,069	879
N7	3,657	1,189.2	867	7,604	44,836	44,400	1,127
N8	4,211	1,365.6	967	7,441	51,203	50,764	1,382
						sum =	

Weighted Results

Notch	EPA Line-Haul WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.4	5.8	10.5	26.5	105.5	104.4	6.0
Low Idle	19.0%	2.6	5.1	10.3	18.8	115.7	114.7	3.4
Idle	19.0%	3.7	8.7	16.0	40.3	160.4	158.7	9.1
N1	6.5%	13.3	6.0	8.1	19.4	152.0	150.6	3.9
N2	6.5%	28.5	11.2	15.1	34.3	381.8	379.0	7.7
N3	5.2%	50.9	18.3	16.5	30.5	548.3	543.8	16.4
N4	4.4%	66.6	23.4	16.2	48.5	771.1	764.8	19.8
N5	3.8%	76.1	26.3	18.4	99.0	836.8	830.3	21.0
N6	3.9%	112.4	38.0	27.2	365.9	1221.2	1211.7	34.3
N7	3.0%	109.7	35.7	26.0	228.1	1345.1	1332.0	33.8
N8	16.2%	682.1	221.2	156.7	1205.4	8294.9	8223.8	223.9
TOTAL	100.0%	1148.5	399.6	320.9	2116.8	13932.9	13813.7	379.4
EPA line-haul duty cycle weighted brake-specific emissions			0.348	0.28	1.8	**12.132**	**12.028**	0.33
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	2.371	4.33	10.93	43.51	43.06	2.47
Low Idle	1.970	4.00	7.33	45.11	44.70	1.33
Idle	2.371	4.33	10.93	43.51	43.06	2.47
N1	0.451	0.61	1.46	11.42	11.31	0.29
N2	0.391	0.53	1.20	13.39	13.29	0.27
N3	0.360	0.32	0.60	10.76	10.68	0.32
N4	0.351	0.24	0.73	11.58	11.48	0.30
N5	0.346	0.24	1.30	10.99	10.90	0.28
N6	0.338	0.24	3.25	10.86	10.78	0.30
N7	0.325	0.24	2.08	12.26	12.14	0.31
N8	0.324	0.23	1.77	12.16	12.06	0.33

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	4.0	8.0	16.1	29.6	182.1	180.4	5.4
Idle	29.9%	5.8	13.8	25.1	63.4	252.4	249.8	14.4
N1	12.4%	25.4	11.5	15.5	37.1	290.0	287.3	7.4
N2	12.3%	53.9	21.1	28.5	64.9	722.5	717.1	14.6
N3	5.8%	56.8	20.5	18.4	34.0	611.6	606.6	18.3
N4	3.6%	54.5	19.1	13.3	39.7	630.9	625.7	16.2
N5	3.6%	72.1	24.9	17.4	93.8	792.8	786.6	19.9
N6	1.5%	43.2	14.6	10.5	140.7	469.7	466.0	13.2
N7	0.2%	7.3	2.4	1.7	15.2	89.7	88.8	2.3
N8	0.8%	33.7	10.9	7.7	59.5	409.6	406.1	11.1
TOTAL	100.0%	356.9	146.7	154.4	578.0	4451.3	4414.4	122.7
EPA switch duty cycle weighted brake-specific emissions			0.411	0.43	1.62	12.47	12.37	0.34
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

BNSF #9754 Test Date 10-09-98 On-Highway Diesel Fuel EM-2677-F Run #3/4

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	19	47.6	135	336	1,155	1,147	46
Low Idle	14	27.2	89	206	829	824	21
Idle	19	47.6	135	336	1,155	1,147	46
N1	205	92.7	142	302	2,276	2,263	66
N2	438	171.0	207	447	4,579	4,556	128
N3	980	353.4	319	608	10,471	10,420	354
N4	1,515	530.5	401	1,078	17,216	17,125	468
N5	2,004	691.8	538	2,409	22,199	22,050	562
N6	2,883	967.7	802	8,525	31,525	31,335	977
N7	3,657	1,190.0	930	7,642	44,453	44,226	1,346
N8	4,211	1,361.0	1,020	7,270	51,275	50,999	1,652
							sum =

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.4	6.0	16.9	42.0	144.4	143.4	5.8
Low Idle	19.0%	2.6	5.2	16.9	39.1	157.5	156.6	4.0
Idle	19.0%	3.6	9.0	25.7	63.8	219.5	217.9	8.7
N1	6.5%	13.3	6.0	9.2	19.6	147.9	147.1	4.3
N2	6.5%	28.5	11.1	13.5	29.1	297.6	296.1	8.3
N3	5.2%	50.9	18.4	16.6	31.6	544.5	541.8	18.4
N4	4.4%	66.7	23.3	17.6	47.4	757.5	753.5	20.6
N5	3.8%	76.2	26.3	20.4	91.5	843.6	837.9	21.4
N6	3.9%	112.4	37.7	31.3	332.5	1229.5	1222.1	38.1
N7	3.0%	109.7	35.7	27.9	229.3	1333.6	1326.8	40.4
N8	16.2%	682.2	220.5	165.2	1177.7	8306.6	8261.9	267.6
TOTAL	100.0%	1148.5	399.2	361.2	2103.7	13982.1	13905.2	437.6
EPA line-haul duty cycle weighted brake-specific emissions			0.348	0.31	1.8	**12.2**	**12.1**	0.38
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

EPA Switch Cycle

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	2.479	7.03	17.50	60.16	59.74	2.40
Low Idle	2.015	6.59	15.26	61.41	61.07	1.56
Idle	2.479	7.03	17.50	60.16	59.74	2.40
N1	0.453	0.69	1.47	11.11	11.05	0.32
N2	0.391	0.47	1.02	10.46	10.41	0.29
N3	0.361	0.33	0.62	10.69	10.63	0.36
N4	0.350	0.26	0.71	11.37	11.31	0.31
N5	0.345	0.27	1.20	11.08	11.00	0.28
N6	0.336	0.28	2.96	10.94	10.87	0.34
N7	0.325	0.25	2.09	12.15	12.09	0.37
N8	0.323	0.24	1.73	12.18	12.11	0.39

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	4.0	8.1	26.6	61.6	247.9	246.5	6.3
Idle	29.9%	5.7	14.2	40.4	100.5	345.3	342.9	13.8
N1	12.4%	25.4	11.5	17.6	37.4	282.2	280.6	8.2
N2	12.3%	53.8	21.0	25.5	55.0	563.2	560.4	15.7
N3	5.8%	56.8	20.5	18.5	35.3	607.3	604.4	20.5
N4	3.6%	54.5	19.1	14.4	38.8	619.8	616.5	16.8
N5	3.6%	72.1	24.9	19.4	86.7	799.2	793.8	20.2
N6	1.5%	43.2	14.5	12.0	127.9	472.9	470.0	14.7
N7	0.2%	7.3	2.4	1.9	15.3	88.9	88.5	2.7
N8	0.8%	33.7	10.9	8.2	58.2	410.2	408.0	13.2
TOTAL	100.0%	356.8	147.2	184.4	616.6	4436.9	4411.6	132.1
EPA switch duty cycle weighted brake-specific emissions			0.413	0.52	1.73	12.44	12.37	0.37
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

BNSF #9754 Test Date 10-12-98 On-Highway Diesel Fuel EM-2677-F Run #4/4

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	19	47.3	154	293	1,214	1,204	42
Low Idle	14	25.3	85	137	849	840	20
Idle	19	47.3	154	293	1,214	1,204	42
N1	205	91.3	141	284	2,312	2,293	51
N2	439	171.4	204	410	4,567	4,524	103
N3	980	354.0	305	568	10,497	10,410	297
N4	1,513	532.5	414	1,187	17,243	17,072	465
N5	2,005	696.0	530	2,896	22,076	21,894	561
N6	2,883	979.7	773	10,389	33,240	32,965	919
N7	3,654	1,196.0	934	8,879	45,264	44,812	1,228
N8	4,208	1,369.2	1,000	7,846	50,093	49,713	1,490
						sum =	42

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.4	5.9	19.3	36.6	151.8	150.5	5.3
Low Idle	19.0%	2.6	4.8	16.2	26.0	161.3	159.5	3.8
Idle	19.0%	3.7	9.0	29.3	55.7	230.7	228.7	8.0
N1	6.5%	13.3	5.9	9.2	18.5	150.3	149.0	3.3
N2	6.5%	28.5	11.1	13.3	26.7	296.9	294.1	6.7
N3	5.2%	51.0	18.4	15.9	29.5	545.8	541.3	15.4
N4	4.4%	66.6	23.4	18.2	52.2	758.7	751.2	20.5
N5	3.8%	76.2	26.4	20.1	110.0	838.9	832.0	21.3
N6	3.9%	112.4	38.2	30.1	405.2	1296.4	1285.7	35.8
N7	3.0%	109.6	35.9	28.0	266.4	1357.9	1344.4	36.8
N8	16.2%	681.7	221.8	162.0	1271.1	8115.1	8053.5	241.4
TOTAL	100.0%	1148.0	401.0	361.5	2297.8	13903.6	13789.7	398.3
EPA line-haul duty cycle weighted brake-specific emissions			0.349	0.31	2.0	**12.111**	**12.012**	0.35
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	2.451	7.98	15.18	62.90	62.36	2.18
Low Idle	1.874	6.30	10.15	62.89	62.19	1.48
Idle	2.451	7.98	15.18	62.90	62.36	2.18
N1	0.446	0.69	1.39	11.29	11.20	0.25
N2	0.391	0.47	0.94	10.42	10.32	0.23
N3	0.361	0.31	0.58	10.71	10.62	0.30
N4	0.352	0.27	0.78	11.39	11.28	0.31
N5	0.347	0.26	1.44	11.01	10.92	0.28
N6	0.340	0.27	3.60	11.53	11.44	0.32
N7	0.327	0.26	2.43	12.39	12.26	0.34
N8	0.325	0.24	1.86	11.90	11.81	0.35

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	4.0	7.6	25.4	41.0	253.9	251.0	6.0
Idle	29.9%	5.8	14.1	46.0	87.6	363.0	359.9	12.6
N1	12.4%	25.4	11.3	17.5	35.2	286.7	284.3	6.3
N2	12.3%	53.9	21.1	25.1	50.4	561.7	556.5	12.7
N3	5.8%	56.9	20.5	17.7	32.9	608.8	603.8	17.2
N4	3.6%	54.5	19.2	14.9	42.7	620.7	614.6	16.7
N5	3.6%	72.2	25.1	19.1	104.3	794.7	788.2	20.2
N6	1.5%	43.2	14.7	11.6	155.8	498.6	494.5	13.8
N7	0.2%	7.3	2.4	1.9	17.8	90.5	89.6	2.5
N8	0.8%	33.7	11.0	8.0	62.8	400.7	397.7	11.9
TOTAL	100.0%	356.9	146.9	187.2	630.5	4479.4	4440.0	119.9
EPA switch duty cycle weighted brake-specific emissions			0.412	0.52	1.77	12.552	12.442	0.34
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

APPENDIX B-4

BNSF No. 9754 Test Results Using High-Sulfur Diesel Fuel

BNSF #9754 Test Date 10-5-98 Nonroad High-Sulfur Diesel Fuel EM-2664-F Run #1/4

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	19	48.0	137	256	1,220	1,197	45
Low Idle	14	27.6	78	119	888	871	20
Idle	19	48.0	137	256	1,220	1,197	45
N1	205	93.0	136	195	2,357	2,316	55
N2	438	173.0	196	472	4,696	4,618	116
N3	980	360.0	296	648	10,497	10,320	315
N4	1,514	541.0	383	1,731	16,903	16,613	525
N5	2,003	709.2	430	3,065	21,965	21,573	801
N6	2,866	994.8	607	10,899	31,749	31,182	1,247
N7	3,651	1,208.4	872	10,537	45,457	44,744	1,284
N8	4,229	1,386.0	989	10,140	51,769	50,917	1,488
							sum =

Weighted Results

Notch	EPA Line-Haul WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.4	6.0	17.1	32.0	152.5	149.7	5.6
Low Idle	19.0%	2.6	5.2	14.8	22.6	168.7	165.5	3.8
Idle	19.0%	3.6	9.1	26.0	48.6	231.8	227.5	8.6
N1	6.5%	13.3	6.0	8.8	12.7	153.2	150.5	3.6
N2	6.5%	28.5	11.2	12.7	30.7	305.2	300.1	7.5
N3	5.2%	51.0	18.7	15.4	33.7	545.8	536.6	16.4
N4	4.4%	66.6	23.8	16.9	76.2	743.7	731.0	23.1
N5	3.8%	76.1	26.9	16.3	116.5	834.7	819.8	30.4
N6	3.9%	111.8	38.8	23.7	425.1	1238.2	1216.1	48.6
N7	3.0%	109.5	36.3	26.2	316.1	1363.7	1342.3	38.5
N8	16.2%	685.0	224.5	160.2	1642.7	8386.6	8248.5	241.1
TOTAL	100.0%	1150.4	406.7	338.2	2756.8	14124.2	13887.7	427.2
EPA line-haul duty cycle weighted brake-specific emissions			0.354	0.29	2.4	**12.3**	**12.1**	0.37
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	2.500	7.14	13.33	63.54	62.36	2.34
Low Idle	2.044	5.78	8.81	65.78	64.53	1.48
Idle	2.500	7.14	13.33	63.54	62.36	2.34
N1	0.454	0.66	0.95	11.51	11.31	0.27
N2	0.395	0.45	1.08	10.71	10.53	0.26
N3	0.367	0.30	0.66	10.71	10.53	0.32
N4	0.357	0.25	1.14	11.17	10.98	0.35
N5	0.354	0.21	1.53	10.97	10.77	0.40
N6	0.347	0.21	3.80	11.08	10.88	0.44
N7	0.331	0.24	2.89	12.45	12.25	0.35
N8	0.328	0.23	2.40	12.24	12.04	0.35

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	4.0	8.3	23.3	35.6	265.5	260.5	6.0
Idle	29.9%	5.7	14.4	41.0	76.5	364.8	358.0	13.5
N1	12.4%	25.4	11.5	16.9	24.2	292.3	287.1	6.8
N2	12.3%	53.9	21.3	24.1	58.1	577.6	568.0	14.3
N3	5.8%	56.8	20.9	17.2	37.6	608.8	598.6	18.3
N4	3.6%	54.5	19.5	13.8	62.3	608.5	598.1	18.9
N5	3.6%	72.1	25.5	15.5	110.3	790.7	776.6	28.8
N6	1.5%	43.0	14.9	9.1	163.5	476.2	467.7	18.7
N7	0.2%	7.3	2.4	1.7	21.1	90.9	89.5	2.6
N8	0.8%	33.8	11.1	7.9	81.1	414.2	407.3	11.9
TOTAL	100.0%	356.6	149.7	170.5	670.3	4489.5	4411.4	139.7
EPA switch duty cycle weighted brake-specific emissions			0.420	0.48	1.88	12.59	12.37	0.39
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

BNSF #9754 Test Date 10-08-98 Nonroad High-Sulfur Diesel Fuel EM-2664-F Run #2/4

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	20	49.8	155	308	1,255	1,241	45
Low Idle	14	27.9	92	149	850	842	20
Idle	20	49.8	155	308	1,255	1,241	45
N1	205	93.3	153	309	2,374	2,353	75
N2	439	172.8	208	401	4,689	4,645	133
N3	980	356.3	343	538	10,412	10,343	397
N4	1,514	534.0	398	979	17,324	17,175	525
N5	2,006	694.8	501	2,181	21,844	21,656	681
N6	2,883	973.2	718	8,496	31,095	30,864	1,092
N7	3,654	1,189.8	977	7,158	45,236	44,887	1,491
N8	4,211	1,366.0	1,050	6,233	50,450	50,025	1,773
							sum =

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.4	6.2	19.4	38.5	156.9	155.2	5.6
Low Idle	19.0%	2.6	5.3	17.5	28.3	161.5	159.9	3.8
Idle	19.0%	3.7	9.5	29.5	58.5	238.5	235.9	8.6
N1	6.5%	13.3	6.1	9.9	20.1	154.3	153.0	4.9
N2	6.5%	28.5	11.2	13.5	26.1	304.8	301.9	8.6
N3	5.2%	50.9	18.5	17.8	28.0	541.4	537.8	20.6
N4	4.4%	66.6	23.5	17.5	43.1	762.3	755.7	23.1
N5	3.8%	76.2	26.4	19.0	82.9	830.1	822.9	25.9
N6	3.9%	112.4	38.0	28.0	331.3	1212.7	1203.7	42.6
N7	3.0%	109.6	35.7	29.3	214.7	1357.1	1346.6	44.7
N8	16.2%	682.2	221.3	170.1	1009.7	8172.9	8104.0	287.2
TOTAL	100.0%	1148.5	401.7	371.6	1881.2	13892.4	13776.6	475.7
EPA line-haul duty cycle weighted brake-specific emissions			0.350	0.32	1.6	**12.1**	**12.0**	0.41
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	2.554	7.95	15.79	64.36	63.66	2.31
Low Idle	2.067	6.81	11.04	62.96	62.35	1.48
Idle	2.554	7.95	15.79	64.36	63.66	2.31
N1	0.456	0.75	1.51	11.60	11.50	0.37
N2	0.394	0.47	0.91	10.69	10.59	0.30
N3	0.364	0.35	0.55	10.63	10.56	0.41
N4	0.353	0.26	0.65	11.44	11.34	0.35
N5	0.346	0.25	1.09	10.89	10.79	0.34
N6	0.338	0.25	2.95	10.79	10.71	0.38
N7	0.326	0.27	1.96	12.38	12.28	0.41
N8	0.324	0.25	1.48	11.98	11.88	0.42

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	4.0	8.3	27.5	44.6	254.2	251.7	6.0
Idle	29.9%	5.8	14.9	46.3	92.1	375.2	371.2	13.5
N1	12.4%	25.4	11.6	19.0	38.3	294.4	291.8	9.3
N2	12.3%	54.0	21.3	25.6	49.3	576.7	571.3	16.4
N3	5.8%	56.8	20.7	19.9	31.2	603.9	599.9	23.0
N4	3.6%	54.5	19.2	14.3	35.2	623.7	618.3	18.9
N5	3.6%	72.2	25.0	18.0	78.5	786.4	779.6	24.5
N6	1.5%	43.2	14.6	10.8	127.4	466.4	463.0	16.4
N7	0.2%	7.3	2.4	2.0	14.3	90.5	89.8	3.0
N8	0.8%	33.7	10.9	8.4	49.9	403.6	400.2	14.2
TOTAL	100.0%	357.0	148.9	191.8	560.9	4475.0	4436.6	145.1
EPA switch duty cycle weighted brake-specific emissions			0.417	0.54	1.57	12.53	12.43	0.41
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

BNSF #9754 Test Date 10-12-98 Nonroad High-Sulkfur Diesel Fuel EM-2664-F Run #3/4

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	19	49.5	147	333	1,290	1,265	43
Low Idle	14	27.8	83	171	919	901	26
Idle	19	49.5	147	333	1,290	1,265	43
N1	205	93.1	133	312	2,320	2,278	59
N2	438	173.3	192	424	4,606	4,527	114
N3	980	356.4	309	607	10,318	10,143	342
N4	1,515	532.8	380	1,123	17,196	16,918	561
N5	2,004	699.6	495	2,634	21,793	21,507	697
N6	2,886	980.0	733	9,614	31,914	31,419	1,136
N7	3,657	1,198.0	924	8,028	45,395	44,756	1,431
N8	4,211	1,370.4	1,008	7,215	52,781	52,038	1,664
							sum =

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.4	6.2	18.4	41.6	161.3	158.1	5.4
Low Idle	19.0%	2.6	5.3	15.8	32.5	174.6	171.2	4.9
Idle	19.0%	3.7	9.4	27.9	63.3	245.1	240.3	8.2
N1	6.5%	13.3	6.1	8.6	20.3	150.8	148.1	3.8
N2	6.5%	28.4	11.3	12.5	27.6	299.4	294.2	7.4
N3	5.2%	50.9	18.5	16.1	31.6	536.5	527.4	17.8
N4	4.4%	66.7	23.4	16.7	49.4	756.6	744.4	24.7
N5	3.8%	76.2	26.6	18.8	100.1	828.1	817.2	26.5
N6	3.9%	112.5	38.2	28.6	374.9	1244.6	1225.3	44.3
N7	3.0%	109.7	35.9	27.7	240.8	1361.9	1342.7	42.9
N8	16.2%	682.2	222.0	163.3	1168.8	8550.5	8430.1	269.6
TOTAL	100.0%	1148.7	402.9	354.4	2150.9	14309.5	14099.1	455.5
EPA line-haul duty cycle weighted brake-specific emissions			0.351	0.31	1.9	**12.5**	**12.3**	0.40
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	2.552	7.58	17.16	66.49	65.19	2.22
Low Idle	2.059	6.15	12.67	68.07	66.74	1.93
Idle	2.552	7.58	17.16	66.49	65.19	2.22
N1	0.455	0.65	1.52	11.34	11.14	0.29
N2	0.396	0.44	0.97	10.53	10.34	0.26
N3	0.364	0.32	0.62	10.53	10.35	0.35
N4	0.352	0.25	0.74	11.35	11.17	0.37
N5	0.349	0.25	1.31	10.87	10.73	0.35
N6	0.340	0.25	3.33	11.06	10.89	0.39
N7	0.328	0.25	2.20	12.41	12.24	0.39
N8	0.325	0.24	1.71	12.53	12.36	0.40

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	4.0	8.3	24.8	51.1	274.8	269.4	7.8
Idle	29.9%	5.8	14.8	44.0	99.6	385.7	378.1	12.9
N1	12.4%	25.4	11.5	16.5	38.7	287.7	282.5	7.3
N2	12.3%	53.8	21.3	23.6	52.2	566.5	556.8	14.0
N3	5.8%	56.8	20.7	17.9	35.2	598.4	588.3	19.8
N4	3.6%	54.5	19.2	13.7	40.4	619.1	609.0	20.2
N5	3.6%	72.1	25.2	17.8	94.8	784.5	774.2	25.1
N6	1.5%	43.3	14.7	11.0	144.2	478.7	471.3	17.0
N7	0.2%	7.3	2.4	1.8	16.1	90.8	89.5	2.9
N8	0.8%	33.7	11.0	8.1	57.7	422.2	416.3	13.3
TOTAL	100.0%	356.8	149.1	179.2	630.0	4508.5	4435.5	140.3
EPA switch duty cycle weighted brake-specific emissions			0.418	0.50	1.77	12.64	12.43	0.39
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

BNSF #9754 Test Date 10-13-98 Nonroad High-Sulfur Diesel Fuel EM-2664-F Run #4/4

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	19	48.5	150	363	1,228	1,213	59
Low Idle	14	27.6	98	185	888	876	24
Idle	19	48.5	150	363	1,228	1,213	59
N1	205	93.0	156	413	2,400	2,368	96
N2	439	173.2	225	544	4,609	4,548	156
N3	980	356.7	352	754	10,347	10,200	256
N4	1,514	536.7	442	1,417	17,009	16,780	605
N5	2,005	700.4	588	2,848	22,196	21,931	738
N6	2,882	978.6	815	7,811	31,680	31,352	1,263
N7	3,657	1,197.6	1,021	6,909	45,545	44,979	1,556
N8	4,209	1,369.9	1,143	7,527	52,711	52,146	1,819
							sum =

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.4	6.1	18.8	45.4	153.5	151.6	7.4
Low Idle	19.0%	2.6	5.2	18.6	35.2	168.7	166.4	4.6
Idle	19.0%	3.7	9.2	28.5	69.0	233.3	230.5	11.2
N1	6.5%	13.3	6.0	10.1	26.8	156.0	153.9	6.2
N2	6.5%	28.5	11.3	14.6	35.4	299.6	295.6	10.1
N3	5.2%	50.9	18.5	18.3	39.2	538.0	530.4	13.3
N4	4.4%	66.6	23.6	19.4	62.3	748.4	738.3	26.6
N5	3.8%	76.2	26.6	22.3	108.2	843.4	833.4	28.0
N6	3.9%	112.4	38.2	31.8	304.6	1235.5	1222.7	49.3
N7	3.0%	109.7	35.9	30.6	207.3	1366.4	1349.4	46.7
N8	16.2%	681.8	221.9	185.2	1219.4	8539.2	8447.7	294.7
TOTAL	100.0%	1148.1	402.6	398.3	2152.8	14282.1	14120.0	498.1
EPA line-haul duty cycle weighted brake-specific emissions			0.351	0.35	1.9	**12.440**	**12.299**	0.43
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

EPA Switch Cycle

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	2.500	7.73	18.71	63.30	62.54	3.04
Low Idle	2.044	7.26	13.70	65.78	64.88	1.78
Idle	2.500	7.73	18.71	63.30	62.54	3.04
N1	0.454	0.76	2.02	11.72	11.56	0.47
N2	0.395	0.51	1.24	10.51	10.37	0.36
N3	0.364	0.36	0.77	10.56	10.41	0.26
N4	0.355	0.29	0.94	11.24	11.09	0.40
N5	0.349	0.29	1.42	11.07	10.94	0.37
N6	0.340	0.28	2.71	10.99	10.88	0.44
N7	0.328	0.28	1.89	12.46	12.30	0.43
N8	0.326	0.27	1.79	12.52	12.39	0.43

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	4.0	8.3	29.3	55.3	265.5	261.9	7.2
Idle	29.9%	5.8	14.5	44.9	108.5	367.2	362.7	17.6
N1	12.4%	25.4	11.5	19.3	51.2	297.6	293.7	11.9
N2	12.3%	53.9	21.3	27.7	66.9	566.9	559.3	19.2
N3	5.8%	56.8	20.7	20.4	43.7	600.1	591.6	14.8
N4	3.6%	54.5	19.3	15.9	51.0	612.3	604.1	21.8
N5	3.6%	72.2	25.2	21.2	102.5	799.1	789.5	26.6
N6	1.5%	43.2	14.7	12.2	117.2	475.2	470.3	18.9
N7	0.2%	7.3	2.4	2.0	13.8	91.1	90.0	3.1
N8	0.8%	33.7	11.0	9.1	60.2	421.7	417.2	14.6
TOTAL	100.0%	356.9	148.8	202.1	670.4	4496.7	4440.2	155.7
EPA switch duty cycle weighted brake-specific emissions			0.417	0.57	1.88	12.601	12.442	0.44
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

APPENDIX B-5

BNSF No. 9754 Smoke Test Summary

SMOKE TEST SUMMARY FOR BNSF NO. 9754

Run #	**ss**	**30-sec**	**3-sec**
Carb Diesel (EM-2663-F)			
# 1	13	17	24
# 2	9	10	17
# 3	11	15	19
Avg	**11**	**14**	**20**
cov	18%	26%	18%
On-Highway Diesel (EM-2677-F)			
# 1	7	9	19
# 2	12	15	17
# 3	11	15	16
# 4	13	17	22
Avg	**11**	**14**	**19**
cov	24%	25%	14%
Nonroad High Sulfur Diesel (EM-2664-F)			
# 1	15	19	27
# 2	10	13	18
# 3	11	15	20
# 4	11	16	22
Avg	**12**	**16**	**22**
cov	19%	16%	18%

APPENDIX C-1

BNSF No. 9696 Test Summary

EPA Line-Haul Duty Cycle Weighting Factors

	obs bsfc	HC	CO	EPA NOx	KH-NOx	PM	BN 9696
	lb/hp-hr	g/hp-hr	g/hp-hr	g/hp-hr	g/hp-hr	g/hp-hr	EMD SD70MAC
Carb Diesel (EM-2663-F)							updated 06-29-99
	0.347	0.34	1.3	11.432	11.407	0.21	
	0.347	0.33	1.1	11.406	11.319	0.23	
	0.344	0.32	0.9	11.529	11.281	0.24	
Avg	**0.346**	**0.331**	**1.10**	**11.455**	**11.336**	**0.226**	
cov	0.5%	4.1%	17.1%	0.6%	0.6%	6.6%	
On-Highway Diesel (EM-2677-F)							
	0.349	0.34	1.0	12.091	11.970	0.27	
	0.349	0.36	1.0	12.036	11.907	0.26	
	0.352	0.32	1.3	11.948	11.814	0.23	
Avg	**0.350**	**0.343**	**1.10**	**12.025**	**11.897**	**0.255**	
cov	0.5%	4.9%	13.5%	0.6%	0.7%	7.6%	
Nonroad High Sulfur Diesel (EM-2664-F)							
	0.352	0.31	1.2	12.165	12.098	0.28	
	0.352	0.33	1.2	12.366	12.199	0.31	
	0.350	0.32	0.9	12.563	12.312	0.28	
Avg	**0.351**	**0.323**	**1.09**	**12.365**	**12.203**	**0.291**	
cov	0.2%	2.9%	12.2%	1.6%	0.9%	5.4%	
	-1.4%	2%	1%	-7%	-7%	-22%	carb vs HS
	-0.4%	6%	1%	-3%	-3%	-12%	on-hwy vs HS
	-0.9%	-3%	-0%	-5%	-5%	-11%	carb vs on-hwy

EPA Switcher Duty Cycle Weighting Factors

	obs bsfc	HC	CO	EPA NOx	KH-NOx	PM	
	lb/hp-hr	g/hp-hr	g/hp-hr	g/hp-hr	g/hp-hr	g/hp-hr	
Carb Diesel (EM-2663-F)							
	0.408	0.54	1.38	11.689	11.657	0.24	
	0.411	0.55	1.22	11.799	11.701	0.26	
	0.408	0.53	0.92	11.863	11.596	0.29	
Avg	**0.409**	**0.542**	**1.17**	**11.784**	**11.651**	**0.263**	
cov	0.3%	1.5%	19.8%	0.7%	0.5%	8.8%	
On-Highway Diesel (EM-2677-F)							
	0.411	0.54	1.13	12.521	12.365	0.33	
	0.413	0.59	1.18	12.314	12.198	0.30	
	0.416	0.54	1.37	12.306	12.163	0.26	
Avg	**0.413**	**0.555**	**1.23**	**12.380**	**12.242**	**0.299**	
cov	0.7%	4.9%	10.3%	1.0%	0.9%	11.2%	
Nonroad High Sulfur Diesel (EM-2664-F)							
	0.416	0.54	1.32	12.292	12.223	0.32	
	0.417	0.56	1.35	12.520	12.347	0.34	
	0.417	0.51	1.08	12.776	12.513	0.31	
Avg	**0.417**	**0.534**	**1.25**	**12.529**	**12.361**	**0.324**	
cov	0.2%	4.8%	12.0%	1.9%	1.2%	4.4%	
	-1.8%	2%	-6%	-6%	-6%	-19%	carb vs HS
	-0.8%	4%	-2%	-1%	-1%	-8%	on-hwy vs HS
	-1.0%	-2%	-5%	-5%	-5%	-12%	carb vs on-hwy

APPENDIX C-2

BNSF No. 9696 Test Results Using CARB Diesel Fuel

BN #9696 Test Date 3-10-99 CARB Diesel Fuel EM-2663-F Run #1/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	19	45.0	168	120	1,045	1,038	27
Low Idle	13	24.5	105	57	756	752	12
Idle	19	45.0	168	120	1,045	1,038	27
N1	205	89.0	150	145	2,149	2,140	37
N2	438	169.0	197	220	4,208	4,197	84
N3	979	355.0	289	368	9,813	9,795	216
N4	1,519	539.0	379	1,868	15,933	15,889	348
N5	1,988	696.0	451	4,496	20,482	20,449	484
N6	2,880	960.0	718	6,427	32,772	32,711	562
N7	3,655	1,181.0	1,023	4,281	48,215	48,118	733
N8	4,173	1,355.0	1,169	4,493	45,985	45,894	817
						sum =	

Weighted Results

Notch	EPA Line-Haul WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.4	5.6	21.0	15.0	130.6	129.8	3.4
Low Idle	19.0%	2.5	4.7	20.0	10.8	143.6	142.9	2.3
Idle	19.0%	3.6	8.6	31.9	22.8	198.6	197.3	5.1
N1	6.5%	13.3	5.8	9.8	9.4	139.7	139.1	2.4
N2	6.5%	28.4	11.0	12.8	14.3	273.5	272.8	5.5
N3	5.2%	50.9	18.5	15.0	19.1	510.3	509.3	11.2
N4	4.4%	66.8	23.7	16.7	82.2	701.1	699.1	15.3
N5	3.8%	75.5	26.4	17.1	170.8	778.3	777.1	18.4
N6	3.9%	112.3	37.4	28.0	250.7	1278.1	1275.7	21.9
N7	3.0%	109.6	35.4	30.7	128.4	1446.5	1443.5	22.0
N8	16.2%	676.0	219.5	189.4	727.9	7449.6	7434.9	132.4
TOTAL	100.0%	1141.5	396.6	392.3	1451.5	13049.8	13021.4	239.8
EPA line-haul duty cycle weighted brake-specific emissions			0.347	0.34	1.3	**11.4**	**11.4**	0.21
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	2.381	8.89	6.35	55.29	54.93	1.43
Low Idle	1.828	7.84	4.25	56.42	56.13	0.90
Idle	2.381	8.89	6.35	55.29	54.93	1.43
N1	0.435	0.73	0.71	10.50	10.46	0.18
N2	0.386	0.45	0.50	9.62	9.59	0.19
N3	0.363	0.30	0.38	10.02	10.00	0.22
N4	0.355	0.25	1.23	10.49	10.46	0.23
N5	0.350	0.23	2.26	10.30	10.29	0.24
N6	0.333	0.25	2.23	11.38	11.36	0.20
N7	0.323	0.28	1.17	13.19	13.17	0.20
N8	0.325	0.28	1.08	11.02	11.00	0.20

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	4.0	7.3	31.4	17.0	226.0	224.9	3.6
Idle	29.9%	5.7	13.5	50.2	35.9	312.5	310.4	8.1
N1	12.4%	25.4	11.0	18.6	18.0	266.5	265.3	4.6
N2	12.3%	53.8	20.8	24.2	27.1	517.6	516.2	10.3
N3	5.8%	56.8	20.6	16.8	21.3	569.2	568.1	12.5
N4	3.6%	54.7	19.4	13.6	67.2	573.6	572.0	12.5
N5	3.6%	71.6	25.1	16.2	161.9	737.4	736.2	17.4
N6	1.5%	43.2	14.4	10.8	96.4	491.6	490.7	8.4
N7	0.2%	7.3	2.4	2.0	8.6	96.4	96.2	1.5
N8	0.8%	33.4	10.8	9.4	35.9	367.9	367.2	6.5
TOTAL	100.0%	355.8	145.3	193.3	489.3	4158.5	4147.1	85.5
EPA switch duty cycle weighted brake-specific emissions			0.408	0.54	1.38	11.69	11.66	0.24
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

BN #9696 Test Date 3-11-99 CARB Diesel Fuel EM-2663-F Run #2/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	19	47.4	185	122	1,090	1,080	37
Low Idle	13	25.5	102	59	768	760	13
Idle	19	47.4	185	122	1,090	1,080	37
N1	205	91.0	148	142	2,163	2,143	42
N2	439	169.0	191	213	4,110	4,075	92
N3	981	355.0	284	389	9,889	9,807	229
N4	1,518	538.0	376	1,772	15,951	15,825	372
N5	1,990	692.0	468	3,691	20,958	20,790	486
N6	2,883	955.0	706	5,031	34,159	33,884	581
N7	3,655	1,179.0	917	3,790	46,255	45,907	786
N8	4,207	1,361.0	1,094	4,126	46,033	45,701	896
							sum =

Weighted Results

Notch	EPA Line-Haul WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.4	5.9	23.1	15.3	136.3	135.0	4.6
Low Idle	19.0%	2.5	4.8	19.4	11.2	145.9	144.5	2.5
Idle	19.0%	3.6	9.0	35.2	23.2	207.1	205.2	7.0
N1	6.5%	13.3	5.9	9.6	9.2	140.6	139.3	2.7
N2	6.5%	28.5	11.0	12.4	13.8	267.2	264.9	6.0
N3	5.2%	51.0	18.5	14.8	20.2	514.2	510.0	11.9
N4	4.4%	66.8	23.7	16.5	78.0	701.8	696.3	16.4
N5	3.8%	75.6	26.3	17.8	140.3	796.4	790.0	18.5
N6	3.9%	112.4	37.2	27.5	196.2	1332.2	1321.5	22.7
N7	3.0%	109.7	35.4	27.5	113.7	1387.7	1377.2	23.6
N8	16.2%	681.6	220.5	177.2	668.4	7457.3	7403.6	145.2
TOTAL	100.0%	1147.4	398.2	381.1	1289.5	13086.7	12987.4	261.0
EPA line-haul duty cycle weighted brake-specific emissions			0.347	0.33	1.1	**11.4**	**11.3**	0.23
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	2.495	9.74	6.42	57.37	56.84	1.95
Low Idle	1.903	7.61	4.40	57.31	56.74	0.97
Idle	2.495	9.74	6.42	57.37	56.84	1.95
N1	0.445	0.72	0.69	10.57	10.47	0.21
N2	0.385	0.44	0.49	9.37	9.29	0.21
N3	0.362	0.29	0.40	10.08	10.00	0.23
N4	0.355	0.25	1.17	10.51	10.43	0.25
N5	0.348	0.24	1.85	10.53	10.45	0.24
N6	0.331	0.24	1.74	11.85	11.75	0.20
N7	0.323	0.25	1.04	12.65	12.56	0.22
N8	0.323	0.26	0.98	10.94	10.86	0.21

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	4.0	7.6	30.5	17.6	229.6	227.3	3.9
Idle	29.9%	5.7	14.2	55.3	36.5	325.9	322.9	11.1
N1	12.4%	25.4	11.3	18.4	17.6	268.2	265.7	5.2
N2	12.3%	53.9	20.8	23.5	26.2	505.5	501.3	11.3
N3	5.8%	56.9	20.6	16.5	22.6	573.6	568.8	13.3
N4	3.6%	54.6	19.4	13.5	63.8	574.2	569.7	13.4
N5	3.6%	71.6	24.9	16.8	132.9	754.5	748.4	17.5
N6	1.5%	43.2	14.3	10.6	75.5	512.4	508.3	8.7
N7	0.2%	7.3	2.4	1.8	7.6	92.5	91.8	1.6
N8	0.8%	33.7	10.9	8.8	33.0	368.3	365.6	7.2
TOTAL	100.0%	356.4	146.3	195.7	433.2	4204.7	4169.9	93.1
EPA switch duty cycle weighted brake-specific emissions			0.411	0.55	1.22	11.80	11.70	0.26
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

BN #9696 Test Date 3-15-99 CARB Diesel Fuel EM-2663-F Run #3/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	19	44.0	170	103	1,025	999	53
Low Idle	14	27.5	110	61	840	818	31
Idle	19	44.0	170	103	1,025	999	53
N1	205	92.0	146	147	2,171	2,118	55
N2	439	171.0	189	214	4,166	4,071	97
N3	981	353.0	286	319	9,757	9,534	230
N4	1,519	533.0	354	1,119	16,299	15,930	366
N5	2,009	692.0	438	2,431	21,267	20,817	405
N6	2,883	946.0	674	3,623	34,194	33,485	550
N7	3,656	1,173.0	874	2,887	46,000	45,046	805
N8	4,211	1,354.0	1,035	3,567	46,937	45,945	951
							sum =

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.4	5.5	21.3	12.9	128.1	124.9	6.6
Low Idle	19.0%	2.6	5.2	20.9	11.6	159.6	155.4	5.9
Idle	19.0%	3.6	8.4	32.3	19.6	194.8	189.8	10.1
N1	6.5%	13.3	6.0	9.5	9.6	141.1	137.7	3.6
N2	6.5%	28.5	11.1	12.3	13.9	270.8	264.6	6.3
N3	5.2%	51.0	18.4	14.9	16.6	507.4	495.8	12.0
N4	4.4%	66.8	23.5	15.6	49.2	717.2	700.9	16.1
N5	3.8%	76.3	26.3	16.6	92.4	808.1	791.0	15.4
N6	3.9%	112.4	36.9	26.3	141.3	1333.6	1305.9	21.5
N7	3.0%	109.7	35.2	26.2	86.6	1380.0	1351.4	24.2
N8	16.2%	682.1	219.3	167.7	577.9	7603.8	7443.0	154.1
TOTAL	100.0%	1148.8	395.7	363.5	1031.5	13244.4	12960.5	275.6
EPA line-haul duty cycle weighted brake-specific emissions			0.344	0.32	0.9	**11.5**	**11.3**	0.24
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	2.292	8.85	5.36	53.39	52.04	2.76
Low Idle	2.037	8.15	4.52	62.22	60.59	2.30
Idle	2.292	8.85	5.36	53.39	52.04	2.76
N1	0.449	0.71	0.72	10.61	10.35	0.27
N2	0.390	0.43	0.49	9.50	9.28	0.22
N3	0.360	0.29	0.33	9.94	9.72	0.23
N4	0.351	0.23	0.74	10.73	10.49	0.24
N5	0.344	0.22	1.21	10.59	10.36	0.20
N6	0.328	0.23	1.26	11.86	11.61	0.19
N7	0.321	0.24	0.79	12.58	12.32	0.22
N8	0.322	0.25	0.85	11.15	10.91	0.23

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	4.0	8.2	32.9	18.2	251.2	244.6	9.3
Idle	29.9%	5.7	13.2	50.8	30.8	306.5	298.8	15.8
N1	12.4%	25.4	11.4	18.1	18.2	269.2	262.7	6.8
N2	12.3%	53.9	21.0	23.2	26.3	512.4	500.7	11.9
N3	5.8%	56.9	20.5	16.6	18.5	565.9	553.0	13.3
N4	3.6%	54.7	19.2	12.7	40.3	586.8	573.5	13.2
N5	3.6%	72.3	24.9	15.8	87.5	765.6	749.4	14.6
N6	1.5%	43.2	14.2	10.1	54.3	512.9	502.3	8.3
N7	0.2%	7.3	2.3	1.7	5.8	92.0	90.1	1.6
N8	0.8%	33.7	10.8	8.3	28.5	375.5	367.6	7.6
TOTAL	100.0%	357.2	145.8	190.3	328.5	4237.9	4142.5	102.4
EPA switch duty cycle weighted brake-specific emissions			0.408	0.53	0.92	11.86	11.60	0.29
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

APPENDIX C-3

BNSF No. 9696 Test Results Using On-Highway Diesel Fuel

BN #9696 Test Date 3-9-99 On-Highway Diesel Fuel EM-2677-F Run #1/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	19	47.0	166	153	1,174	1,151	92
Low Idle	13	25.2	94	67	808	792	29
Idle	19	47.0	166	153	1,174	1,151	92
N1	205	88.0	148	153	2,222	2,183	69
N2	438	169.2	186	221	4,489	4,435	75
N3	980	357.6	309	339	10,590	10,464	207
N4	1,519	541.2	404	1,511	17,061	16,876	389
N5	1,996	699.6	478	3,169	22,431	22,191	496
N6	2,883	957.6	715	4,464	34,538	34,176	695
N7	3,656	1,182.0	944	3,244	48,527	48,062	874
N8	4,210	1,370.4	1,206	3,599	49,167	48,734	1,039
						sum =	

Weighted Results

Notch	EPA Line-Haul WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.4	5.9	20.8	19.1	146.8	143.8	11.5
Low Idle	19.0%	2.5	4.8	17.9	12.7	153.5	150.5	5.5
Idle	19.0%	3.6	8.9	31.5	29.1	223.1	218.6	17.5
N1	6.5%	13.3	5.7	9.6	9.9	144.4	141.9	4.5
N2	6.5%	28.5	11.0	12.1	14.4	291.8	288.3	4.9
N3	5.2%	50.9	18.6	16.1	17.6	550.7	544.1	10.8
N4	4.4%	66.9	23.8	17.8	66.5	750.7	742.6	17.1
N5	3.8%	75.8	26.6	18.2	120.4	852.4	843.3	18.8
N6	3.9%	112.4	37.3	27.9	174.1	1347.0	1332.9	27.1
N7	3.0%	109.7	35.5	28.3	97.3	1455.8	1441.9	26.2
N8	16.2%	682.0	222.0	195.4	583.0	7965.1	7894.9	168.3
TOTAL	100.0%	1148.1	400.1	395.4	1144.2	13881.1	13742.7	312.2
EPA line-haul duty cycle weighted brake-specific emissions			0.349	0.34	1.0	**12.1**	**12.0**	0.27
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	2.474	8.74	8.05	61.79	60.56	4.84
Low Idle	1.881	7.01	5.00	60.30	59.11	2.16
Idle	2.474	8.74	8.05	61.79	60.56	4.84
N1	0.430	0.72	0.75	10.86	10.67	0.34
N2	0.386	0.42	0.50	10.24	10.12	0.17
N3	0.365	0.32	0.35	10.81	10.68	0.21
N4	0.356	0.27	0.99	11.23	11.11	0.26
N5	0.351	0.24	1.59	11.24	11.12	0.25
N6	0.332	0.25	1.55	11.98	11.85	0.24
N7	0.323	0.26	0.89	13.27	13.15	0.24
N8	0.326	0.29	0.85	11.68	11.58	0.25

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	4.0	7.5	28.1	20.0	241.6	236.8	8.7
Idle	29.9%	5.7	14.1	49.6	45.7	351.0	344.0	27.5
N1	12.4%	25.4	10.9	18.4	19.0	275.5	270.7	8.6
N2	12.3%	53.9	20.8	22.9	27.2	552.1	545.5	9.2
N3	5.8%	56.8	20.7	17.9	19.7	614.2	606.9	12.0
N4	3.6%	54.7	19.5	14.5	54.4	614.2	607.6	14.0
N5	3.6%	71.8	25.2	17.2	114.1	807.5	798.9	17.9
N6	1.5%	43.2	14.4	10.7	67.0	518.1	512.6	10.4
N7	0.2%	7.3	2.4	1.9	6.5	97.1	96.1	1.7
N8	0.8%	33.7	11.0	9.6	28.8	393.3	389.9	8.3
TOTAL	100.0%	356.6	146.4	190.9	402.3	4464.7	4409.0	118.3
EPA switch duty cycle weighted brake-specific emissions			0.411	0.54	1.13	12.52	12.37	0.33
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

BN #9696 Test Date 3-10-99 On-Highway Diesel Fuel EM-2677-F Run #2/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	18.9	46.2	182	155	1151	1,140	46
Low Idle	13	26.5	107	74	871	862	15
Idle	18.9	46.2	182	155	1151	1,140	46
N1	205	92.0	157	156	2,402	2,380	50
N2	438	170.0	218	238	4,229	4,192	109
N3	980	358.0	325	368	10,062	9,972	276
N4	1,519	540.0	428	1,575	16,343	16,201	396
N5	1,995	698.0	528	3,441	21,700	21,510	515
N6	2,883	958.0	765	4,447	34,862	34,520	666
N7	3,656	1,184.0	986	3,288	48,398	47,901	886
N8	4,209	1,370.0	1,201	3,765	49,250	48,677	1,026
							sum =

Weighted Results

Notch	EPA Line-Haul WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.4	5.8	22.8	19.4	143.9	142.5	5.8
Low Idle	19.0%	2.5	5.0	20.3	14.1	165.5	163.7	2.9
Idle	19.0%	3.6	8.8	34.6	29.5	218.7	216.5	8.7
N1	6.5%	13.3	6.0	10.2	10.1	156.1	154.7	3.3
N2	6.5%	28.5	11.1	14.2	15.5	274.9	272.5	7.1
N3	5.2%	50.9	18.6	16.9	19.1	523.2	518.5	14.4
N4	4.4%	66.8	23.8	18.8	69.3	719.1	712.8	17.4
N5	3.8%	75.8	26.5	20.1	130.8	824.6	817.4	19.6
N6	3.9%	112.5	37.4	29.8	173.4	1359.6	1346.3	26.0
N7	3.0%	109.7	35.5	29.6	98.6	1451.9	1437.0	26.6
N8	16.2%	681.9	221.9	194.6	609.9	7978.5	7885.7	166.2
TOTAL	100.0%	1147.9	400.3	411.8	1189.7	13816.0	13667.6	297.8
EPA line-haul duty cycle weighted brake-specific emissions			0.349	0.36	1.0	**12.0**	**11.9**	0.26
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	2.444	9.63	8.20	60.90	60.30	2.43
Low Idle	1.978	7.99	5.52	65.00	64.31	1.12
Idle	2.444	9.63	8.20	60.90	60.30	2.43
N1	0.450	0.77	0.76	11.74	11.63	0.24
N2	0.388	0.50	0.54	9.65	9.56	0.25
N3	0.365	0.33	0.38	10.27	10.18	0.28
N4	0.356	0.28	1.04	10.76	10.67	0.26
N5	0.350	0.26	1.72	10.88	10.78	0.26
N6	0.332	0.27	1.54	12.09	11.97	0.23
N7	0.324	0.27	0.90	13.24	13.10	0.24
N8	0.325	0.29	0.89	11.70	11.56	0.24

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	4.0	7.9	32.0	22.1	260.4	257.7	4.5
Idle	29.9%	5.7	13.8	54.4	46.3	344.1	340.8	13.8
N1	12.4%	25.4	11.4	19.5	19.3	297.8	295.1	6.2
N2	12.3%	53.9	20.9	26.8	29.3	520.2	515.6	13.4
N3	5.8%	56.8	20.8	18.9	21.3	583.6	578.4	16.0
N4	3.6%	54.7	19.4	15.4	56.7	588.3	583.2	14.3
N5	3.6%	71.8	25.1	19.0	123.9	781.2	774.4	18.5
N6	1.5%	43.3	14.4	11.5	66.7	522.9	517.8	10.0
N7	0.2%	7.3	2.4	2.0	6.6	96.8	95.8	1.8
N8	0.8%	33.7	11.0	9.6	30.1	394.0	389.4	8.2
TOTAL	100.0%	356.5	147.1	209.0	422.4	4389.5	4348.1	106.6
EPA switch duty cycle weighted brake-specific emissions			0.413	0.59	1.18	12.31	12.20	0.30
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

BN #9696 Test Date 3-12-99 On-Highway Diesel Fuel EM-2677-F Run #3/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	19	48.6	190	168	1,239	1,220	42
Low Idle	13	26.0	106	77	867	855	14
Idle	19	48.6	190	168	1,239	1,220	42
N1	205	91.0	133	171	2,325	2,298	31
N2	438	172.0	189	261	4,412	4,361	85
N3	980	358.0	287	409	10,185	10,068	203
N4	1,519	545.0	355	2,031	15,692	15,525	398
N5	1,965	693.0	422	3,714	20,810	20,583	505
N6	2,881	963.0	671	5,551	34,819	34,427	659
N7	3,652	1,194.0	858	4,140	47,525	46,997	766
N8	4,197	1,375.0	1,065	4,732	48,691	48,154	917
						sum =	

Weighted Results

Notch	EPA Line-Haul WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.4	6.1	23.8	21.0	154.9	152.6	5.3
Low Idle	19.0%	2.5	4.9	20.1	14.6	164.7	162.5	2.7
Idle	19.0%	3.6	9.2	36.1	31.9	235.4	231.9	8.0
N1	6.5%	13.3	5.9	8.6	11.1	151.1	149.4	2.0
N2	6.5%	28.4	11.2	12.3	17.0	286.8	283.5	5.5
N3	5.2%	51.0	18.6	14.9	21.3	529.6	523.5	10.6
N4	4.4%	66.8	24.0	15.6	89.4	690.4	683.1	17.5
N5	3.8%	74.7	26.3	16.0	141.1	790.8	782.2	19.2
N6	3.9%	112.4	37.6	26.2	216.5	1357.9	1342.6	25.7
N7	3.0%	109.6	35.8	25.7	124.2	1425.8	1409.9	23.0
N8	16.2%	679.8	222.8	172.5	766.6	7887.9	7800.9	148.6
TOTAL	100.0%	1144.5	402.4	371.9	1454.7	13675.4	13522.1	267.9
EPA line-haul duty cycle weighted brake-specific emissions			0.352	0.32	1.3	**11.9**	**11.8**	0.23
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	2.531	9.90	8.75	64.53	63.56	2.19
Low Idle	1.940	7.91	5.75	64.70	63.83	1.04
Idle	2.531	9.90	8.75	64.53	63.56	2.19
N1	0.445	0.65	0.84	11.36	11.22	0.15
N2	0.393	0.43	0.60	10.08	9.97	0.19
N3	0.365	0.29	0.42	10.39	10.27	0.21
N4	0.359	0.23	1.34	10.33	10.22	0.26
N5	0.353	0.21	1.89	10.59	10.48	0.26
N6	0.334	0.23	1.93	12.09	11.95	0.23
N7	0.327	0.23	1.13	13.01	12.87	0.21
N8	0.328	0.25	1.13	11.60	11.47	0.22

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	4.0	7.8	31.7	23.0	259.2	255.8	4.2
Idle	29.9%	5.7	14.5	56.8	50.2	370.5	364.9	12.6
N1	12.4%	25.4	11.3	16.5	21.2	288.3	284.9	3.8
N2	12.3%	53.8	21.2	23.2	32.1	542.7	536.4	10.5
N3	5.8%	56.9	20.8	16.6	23.7	590.7	584.0	11.8
N4	3.6%	54.7	19.6	12.8	73.1	564.9	558.9	14.3
N5	3.6%	70.7	24.9	15.2	133.7	749.2	741.0	18.2
N6	1.5%	43.2	14.4	10.1	83.3	522.3	516.4	9.9
N7	0.2%	7.3	2.4	1.7	8.3	95.1	94.0	1.5
N8	0.8%	33.6	11.0	8.5	37.9	389.5	385.2	7.3
TOTAL	100.0%	355.3	147.9	193.2	486.5	4372.3	4321.5	94.1
EPA switch duty cycle weighted brake-specific emissions			0.416	0.54	1.37	12.31	12.16	0.26
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

APPENDIX C-4

BNSF No. 9696 Test Results Using High-Sulfur Diesel Fuel

BN #9696 Test Date 3-11-99 Nonroad High-Sulfur Diesel Fuel EM-2664-F Run #1/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	19	48.0	183	153	1,249	1,244	47
Low Idle	13	25.5	100	70	857	852	15
Idle	19	48.0	183	153	1,249	1,244	47
N1	205	91.0	147	153	2,303	2,288	42
N2	439	172.0	194	254	4,324	4,299	99
N3	979	360.0	279	390	9,993	9,936	266
N4	1,520	546.0	361	1,932	15,963	15,872	504
N5	1,984	702.0	433	3,901	21,211	21,087	628
N6	2,883	967.0	627	5,462	34,305	34,116	776
N7	3,653	1,190.0	818	3,504	48,840	48,583	909
N8	4,204	1,378.0	1,026	4,135	50,191	49,917	1,106
						sum =	

Weighted Results

Notch	EPA Line-Haul WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.4	6.0	22.9	19.1	156.1	155.5	5.9
Low Idle	19.0%	2.5	4.8	19.0	13.3	162.8	161.8	2.9
Idle	19.0%	3.6	9.1	34.8	29.1	237.3	236.3	8.9
N1	6.5%	13.3	5.9	9.6	9.9	149.7	148.7	2.7
N2	6.5%	28.5	11.2	12.6	16.5	281.1	279.4	6.4
N3	5.2%	50.9	18.7	14.5	20.3	519.6	516.7	13.8
N4	4.4%	66.9	24.0	15.9	85.0	702.4	698.4	22.2
N5	3.8%	75.4	26.7	16.5	148.2	806.0	801.3	23.9
N6	3.9%	112.5	37.7	24.5	213.0	1337.9	1330.5	30.3
N7	3.0%	109.6	35.7	24.5	105.1	1465.2	1457.5	27.3
N8	16.2%	681.0	223.2	166.2	669.9	8130.9	8086.6	179.2
TOTAL	100.0%	1146.7	403.1	360.9	1329.5	13949.1	13872.8	323.4

EPA line-haul duty cycle weighted brake-specific emissions	0.352	0.31	1.2	**12.2**	**12.1**	0.28
EPA line-haul duty cycle maximum Tier 0		1.00	5.0	9.5	9.5	0.60

EPA Switch Cycle

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	2.500	9.53	7.97	65.05	64.78	2.45
Low Idle	1.903	7.46	5.22	63.96	63.56	1.12
Idle	2.500	9.53	7.97	65.05	64.78	2.45
N1	0.445	0.72	0.75	11.25	11.18	0.21
N2	0.392	0.44	0.58	9.86	9.80	0.23
N3	0.368	0.28	0.40	10.20	10.15	0.27
N4	0.359	0.24	1.27	10.50	10.44	0.33
N5	0.354	0.22	1.97	10.69	10.63	0.32
N6	0.335	0.22	1.89	11.90	11.83	0.27
N7	0.326	0.22	0.96	13.37	13.30	0.25
N8	0.328	0.24	0.98	11.94	11.87	0.26

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	4.0	7.6	29.9	20.9	256.2	254.7	4.5
Idle	29.9%	5.7	14.4	54.7	45.7	373.5	371.9	14.1
N1	12.4%	25.4	11.3	18.2	19.0	285.6	283.8	5.2
N2	12.3%	53.9	21.2	23.9	31.2	531.9	528.8	12.2
N3	5.8%	56.8	20.9	16.2	22.6	579.6	576.3	15.4
N4	3.6%	54.7	19.7	13.0	69.6	574.7	571.4	18.1
N5	3.6%	71.4	25.3	15.6	140.4	763.6	759.1	22.6
N6	1.5%	43.3	14.5	9.4	81.9	514.6	511.7	11.6
N7	0.2%	7.3	2.4	1.6	7.0	97.7	97.2	1.8
N8	0.8%	33.6	11.0	8.2	33.1	401.5	399.3	8.8
TOTAL	100.0%	356.2	148.1	190.7	471.5	4378.8	4354.2	114.4

EPA switch duty cycle weighted brake-specific emissions	0.416	0.54	1.32	12.29	12.22	0.32
EPA switch cycle maximum Tier 0		2.10	8.0	14.0	14.0	0.72

BN #9696 Test Date 3-12-99 Nonroad High-Sulfur Diesel Fuel EM-2664-F Run #2/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	19	48.0	187	161	1,248	1,230	44
Low Idle	13	26.0	103	74	899	886	19
Idle	19	48.0	187	161	1,248	1,230	44
N1	205	91.0	143	170	2,303	2,271	43
N2	438	173.0	201	261	4,384	4,323	105
N3	980	361.0	304	391	10,236	10,098	270
N4	1,517	546.0	389	2,000	16,261	16,040	531
N5	1,972	699.0	471	3,919	21,463	21,163	669
N6	2,883	964.0	672	5,214	35,019	34,542	851
N7	3,657	1,191.0	897	3,635	49,853	49,184	957
N8	4,208	1,379.0	1,095	4,192	50,976	50,291	1,249
						sum =	

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.4	6.0	23.4	20.1	156.0	153.8	5.5
Low Idle	19.0%	2.5	4.9	19.6	14.1	170.8	168.4	3.6
Idle	19.0%	3.6	9.1	35.5	30.6	237.1	233.7	8.4
N1	6.5%	13.3	5.9	9.3	11.1	149.7	147.6	2.8
N2	6.5%	28.4	11.2	13.1	17.0	285.0	281.0	6.8
N3	5.2%	51.0	18.8	15.8	20.3	532.3	525.1	14.0
N4	4.4%	66.8	24.0	17.1	88.0	715.5	705.7	23.4
N5	3.8%	74.9	26.6	17.9	148.9	815.6	804.2	25.4
N6	3.9%	112.4	37.6	26.2	203.3	1365.7	1347.1	33.2
N7	3.0%	109.7	35.7	26.9	109.1	1495.6	1475.5	28.7
N8	16.2%	681.7	223.4	177.4	679.1	8258.1	8147.2	202.3
TOTAL	100.0%	1146.8	403.3	382.2	1341.5	14181.4	13989.4	354.2
EPA line-haul duty cycle weighted brake-specific emissions			0.352	0.33	1.2	**12.4**	**12.2**	0.31
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	2.526	9.84	8.47	65.68	64.75	2.32
Low Idle	1.940	7.69	5.52	67.09	66.15	1.42
Idle	2.526	9.84	8.47	65.68	64.75	2.32
N1	0.445	0.70	0.83	11.26	11.10	0.21
N2	0.395	0.46	0.60	10.02	9.88	0.24
N3	0.368	0.31	0.40	10.44	10.30	0.28
N4	0.360	0.26	1.32	10.72	10.57	0.35
N5	0.355	0.24	1.99	10.89	10.73	0.34
N6	0.334	0.23	1.81	12.15	11.98	0.30
N7	0.326	0.25	0.99	13.63	13.45	0.26
N8	0.328	0.26	1.00	12.11	11.95	0.30

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	4.0	7.8	30.8	22.1	268.8	265.0	5.7
Idle	29.9%	5.7	14.4	55.9	48.1	373.2	367.8	13.2
N1	12.4%	25.4	11.3	17.7	21.1	285.6	281.6	5.3
N2	12.3%	53.8	21.3	24.7	32.1	539.2	531.7	12.9
N3	5.8%	56.9	20.9	17.6	22.7	593.7	585.7	15.7
N4	3.6%	54.6	19.7	14.0	72.0	585.4	577.4	19.1
N5	3.6%	71.0	25.2	17.0	141.1	772.7	761.9	24.1
N6	1.5%	43.2	14.5	10.1	78.2	525.3	518.1	12.8
N7	0.2%	7.3	2.4	1.8	7.3	99.7	98.4	1.9
N8	0.8%	33.7	11.0	8.8	33.5	407.8	402.3	10.0
TOTAL	100.0%	355.5	148.3	198.4	478.2	4451.3	4390.0	120.6
EPA switch duty cycle weighted brake-specific emissions			0.417	0.56	1.35	12.52	12.35	0.34
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

BN #9696 Test Date 3-15-99 Nonroad High-Sulfur Diesel Fuel EM-2664-F Run #3/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	19	51.0	155	156	1,342	1,311	41
Low Idle	13	26.3	91	67	851	832	18
Idle	19	51.0	155	156	1,342	1,311	41
N1	205	91.0	132	161	2,223	2,177	45
N2	439	172.0	190	241	4,468	4,377	100
N3	982	359.0	290	328	10,538	10,325	272
N4	1,519	540.0	355	1,282	17,134	16,787	455
N5	2,001	702.0	471	2,910	22,384	21,938	592
N6	2,884	961.0	705	4,349	35,497	34,786	750
N7	3,656	1,184.0	908	2,860	50,126	49,127	923
N8	4,208	1,370.0	1,110	3,373	51,629	50,607	1,133
							sum =

Weighted Results

Notch	EPA Line-Haul WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.4	6.4	19.4	19.5	167.8	163.9	5.1
Low Idle	19.0%	2.5	5.0	17.3	12.7	161.7	158.0	3.4
Idle	19.0%	3.7	9.7	29.5	29.6	255.0	249.1	7.8
N1	6.5%	13.3	5.9	8.6	10.5	144.5	141.5	2.9
N2	6.5%	28.5	11.2	12.4	15.7	290.4	284.5	6.5
N3	5.2%	51.0	18.7	15.1	17.1	548.0	536.9	14.1
N4	4.4%	66.8	23.8	15.6	56.4	753.9	738.6	20.0
N5	3.8%	76.0	26.7	17.9	110.6	850.6	833.6	22.5
N6	3.9%	112.5	37.5	27.5	169.6	1384.4	1356.6	29.3
N7	3.0%	109.7	35.5	27.2	85.8	1503.8	1473.8	27.7
N8	16.2%	681.6	221.9	179.8	546.4	8363.9	8198.3	183.5
TOTAL	100.0%	1148.1	402.2	370.2	1073.9	14423.9	14135.0	322.9
EPA line-haul duty cycle weighted brake-specific emissions			0.350	0.32	0.9	**12.6**	**12.3**	0.28
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	2.642	8.03	8.08	69.53	67.94	2.12
Low Idle	1.963	6.79	5.00	63.51	62.07	1.34
Idle	2.642	8.03	8.08	69.53	67.94	2.12
N1	0.445	0.65	0.79	10.87	10.64	0.22
N2	0.392	0.43	0.55	10.19	9.98	0.23
N3	0.366	0.30	0.33	10.74	10.52	0.28
N4	0.356	0.23	0.84	11.28	11.05	0.30
N5	0.351	0.24	1.45	11.19	10.96	0.30
N6	0.333	0.24	1.51	12.31	12.06	0.26
N7	0.324	0.25	0.78	13.71	13.44	0.25
N8	0.326	0.26	0.80	12.27	12.03	0.27

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	4.0	7.9	27.2	20.0	254.4	248.7	5.4
Idle	29.9%	5.8	15.2	46.3	46.6	401.3	392.1	12.3
N1	12.4%	25.4	11.3	16.4	20.0	275.7	269.9	5.6
N2	12.3%	53.9	21.2	23.4	29.6	549.6	538.3	12.3
N3	5.8%	56.9	20.8	16.8	19.0	611.2	598.8	15.8
N4	3.6%	54.7	19.4	12.8	46.2	616.8	604.3	16.4
N5	3.6%	72.0	25.3	17.0	104.8	805.8	789.8	21.3
N6	1.5%	43.3	14.4	10.6	65.2	532.5	521.8	11.3
N7	0.2%	7.3	2.4	1.8	5.7	100.3	98.3	1.8
N8	0.8%	33.7	11.0	8.9	27.0	413.0	404.9	9.1
TOTAL	100.0%	357.0	148.8	181.1	384.2	4560.5	4466.8	111.1
EPA switch duty cycle weighted brake-specific emissions			0.417	0.51	1.08	12.78	12.51	0.31
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

APPENDIX C-5

BNSF No. 9696 Smoke Test Summary

SMOKE TEST SUMMARY FOR BNSF NO. 9696

Run #	**ss**	**30-sec**	**3-sec**
Carb Diesel (EM-2663-F)			
# 1	13	15	25
# 2	12	14	22
# 3	8	10	15
Avg	**11**	**13**	**21**
cov	24%	20%	25%
On-Highway Diesel (EM-2677-F)			
# 1	9	12	21
# 2	9	12	21
# 3	15	19	28
Avg	**11**	**14**	**23**
cov	31%	28%	17%
Nonroad High Sulfur Diesel (EM-2664-F)			
# 1	13	15	28
# 2	14	18	30
# 3	10	11	19
Avg	**12**	**15**	**26**
cov	17%	24%	23%

updated 3/21/99 sgf

APPENDIX D-1

UP No. 9724 Test Summary

EPA Line-Haul Duty Cycle Weighting Factors

	obs bsfc	HC	CO	EPA NOx	KH-NOx	PM	
	lb/hp-hr	g/hp-hr	g/hp-hr	g/hp-hr	g/hp-hr	g/hp-hr	
Carb Diesel (EM-2663-F)							
	0.349	0.40	1.4	11.418	11.314	0.14	
	0.350	0.41	1.3	11.325	11.197	0.14	
	0.350	0.39	1.5	11.255	11.144	0.13	
Avg	**0.349**	**0.399**	**1.40**	**11.332**	**11.218**	**0.138**	
cov	0.1%	1.6%	8.6%	0.7%	0.8%	3.6%	
On-Highway Diesel (EM-2677-F)							
	0.353	0.41	1.5	11.555	11.432	0.15	
	0.352	0.44	1.2	12.137	12.078	0.14	
	0.351	0.43	1.4	11.774	11.654	0.13	
Avg	**0.352**	**0.428**	**1.36**	**11.822**	**11.721**	**0.140**	
cov	0.2%	3.4%	10.0%	2.5%	2.8%	5.7%	
Nonroad High Sulfur Diesel (EM-2664-F)							
	0.353	0.41	1.3	12.244	12.050	0.22	
	0.351	0.42	1.3	12.432	12.390	0.21	
	0.356	0.37	1.5	12.278	12.239	0.25	
Avg	**0.353**	**0.397**	**1.35**	**12.318**	**12.226**	**0.226**	
cov	0.7%	6.9%	7.4%	0.8%	1.4%	8.5%	
0.3% Sulfur Diesel (EM-2708-F)							
	0.353	0.42	1.3	12.193	12.035	0.20	
	0.353	0.40	1.4	11.828	11.814	0.19	
	0.354	0.40	1.5	11.952	11.802	0.19	
Avg	**0.353**	**0.408**	**1.38**	**11.991**	**11.884**	**0.191**	
cov	0.1%	2.9%	7.5%	1.5%	1.1%	4.1%	
	-1.1%	0%	3%	-8%	-8%	-39%	carb vs HS
	-0.3%	8%	1%	-4%	-4%	-38%	on-hwy vs HS
	-0.8%	-7%	2%	-4%	-4.3%	-2%	carb vs on-hwy

Note: EPA NOx = full NOx correction factor
Note: KH NOx = only ambient air humidity NOx correction factor applied

	-1.1%	-2.2%	1.4%	-5.5%	-5.6%	-28.0%	carb vs 0.3% S

UP 9724
GE DASH9-44CW
updated 06-29-99

EPA Switcher Duty Cycle Weighting Factors

	obs bsfc	HC	CO	EPA NOx	KH-NOx	PM	
	lb/hp-hr	g/hp-hr	g/hp-hr	g/hp-hr	g/hp-hr	g/hp-hr	
Carb Diesel (EM-2663-F)							
	0.390	0.74	2.16	11.778	11.664	0.25	
	0.394	0.77	2.02	11.992	11.865	0.28	
	0.390	0.72	2.12	11.830	11.711	0.25	
Avg	**0.391**	**0.742**	**2.10**	**11.867**	**11.747**	**0.261**	
cov	0.6%	3.3%	3.4%	0.9%	0.9%	6.0%	
On-Highway Diesel (EM-2677-F)							
	0.393	0.71	2.17	12.321	12.221	0.27	
	0.397	0.85	1.94	12.821	12.756	0.30	
	0.392	0.80	2.11	12.642	12.520	0.24	
Avg	**0.394**	**0.787**	**2.07**	**12.595**	**12.499**	**0.271**	
cov	0.7%	8.8%	5.8%	2.0%	2.1%	11.9%	
Nonroad High Sulfur Diesel (EM-2664-F)							
	0.398	0.77	1.96	13.068	12.865	0.33	
	0.395	0.76	1.94	12.977	12.929	0.32	
	0.399	0.63	2.22	13.036	12.969	0.33	
Avg	**0.397**	**0.722**	**2.04**	**13.027**	**12.921**	**0.329**	
cov	0.5%	10.8%	7.7%	0.4%	0.4%	1.5%	
0.3% Sulfur Diesel (EM-2708-F)							
	0.399	0.83	2.00	12.964	12.786	0.37	
	0.395	0.76	2.10	12.735	12.722	0.30	
	0.396	0.79	2.11	12.936	12.775	0.30	
Avg	**0.397**	**0.793**	**2.07**	**12.879**	**12.761**	**0.323**	
cov	0.5%	4.4%	2.9%	1.0%	0.3%	11.8%	
	-1.5%	3%	3%	-9%	-9%	-21%	carb vs HS
	-0.8%	9%	2%	-3%	-3%	-18%	on-hwy vs HS
	-0.7%	-6%	1%	-6%	-6%	-4%	carb vs on-hwy

APPENDIX D-2

UP No. 9724 Test Results Using CARB Diesel Fuel

UP #9724 Test Date 11-29-98 CARB Diesel Fuel EM-2663-F Run #1/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	36	45.0	76	358	942	931	62
Low Idle	21	25.2	291	282	311	308	49
Idle	21	28.5	202	206	591	585	31
N1	198	79.0	125	131	1,592	1,576	57
N2	499	184.0	236	411	4,502	4,458	131
N3	1,033	391.0	474	1,942	12,427	12,305	256
N4	1,552	568.0	442	4,685	19,408	19,216	339
N5	2,222	781.0	641	5,659	28,786	28,514	338
N6	2,938	991.0	824	5,532	36,019	35,653	374
N7	3,663	1,209.0	1,064	4,347	44,497	44,117	368
N8	4,498	1,493.0	1,381	4,410	48,647	48,223	445
						sum =	

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	4.5	5.6	9.5	44.8	117.8	116.4	7.8
Low Idle	19.0%	4.0	4.8	55.3	53.6	59.1	58.5	9.3
Idle	19.0%	4.0	5.4	38.4	39.1	112.3	111.1	5.9
N1	6.5%	12.9	5.1	8.1	8.5	103.5	102.4	3.7
N2	6.5%	32.4	12.0	15.3	26.7	292.6	289.8	8.5
N3	5.2%	53.7	20.3	24.6	101.0	646.2	639.8	13.3
N4	4.4%	68.3	25.0	19.4	206.1	854.0	845.5	14.9
N5	3.8%	84.4	29.7	24.4	215.0	1093.9	1083.5	12.8
N6	3.9%	114.6	38.6	32.1	215.7	1404.7	1390.5	14.6
N7	3.0%	109.9	36.3	31.9	130.4	1334.9	1323.5	11.0
N8	16.2%	728.7	241.9	223.7	714.4	7880.8	7812.1	72.1
TOTAL	100.0%	1217.4	424.7	482.9	1755.4	13899.7	13773.1	174.0
EPA line-haul duty cycle weighted brake-specific emissions			0.349	0.40	1.4	**11.4**	**11.3**	0.14
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	1.250	2.11	9.94	26.17	25.87	1.72
Low Idle	1.200	13.86	13.43	14.81	14.65	2.33
Idle	1.357	9.62	9.81	28.14	27.84	1.48
N1	0.399	0.63	0.66	8.04	7.96	0.29
N2	0.369	0.47	0.82	9.02	8.93	0.26
N3	0.379	0.46	1.88	12.03	11.91	0.25
N4	0.366	0.28	3.02	12.51	12.38	0.22
N5	0.351	0.29	2.55	12.95	12.83	0.15
N6	0.337	0.28	1.88	12.26	12.14	0.13
N7	0.330	0.29	1.19	12.15	12.04	0.10
N8	0.332	0.31	0.98	10.82	10.72	0.10

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	6.3	7.5	87.0	84.3	93.0	92.0	14.7
Idle	29.9%	6.3	8.5	60.4	61.6	176.7	174.8	9.3
N1	12.4%	24.6	9.8	15.5	16.2	197.4	195.4	7.1
N2	12.3%	61.4	22.6	29.0	50.6	553.7	548.4	16.1
N3	5.8%	59.9	22.7	27.5	112.6	720.8	713.7	14.8
N4	3.6%	55.9	20.4	15.9	168.7	698.7	691.8	12.2
N5	3.6%	80.0	28.1	23.1	203.7	1036.3	1026.5	12.2
N6	1.5%	44.1	14.9	12.4	83.0	540.3	534.8	5.6
N7	0.2%	7.3	2.4	2.1	8.7	89.0	88.2	0.7
N8	0.8%	36.0	11.9	11.0	35.3	389.2	385.8	3.6
TOTAL	100.0%	381.6	149.0	284.0	824.7	4495.1	4451.3	96.2
EPA switch duty cycle weighted brake-specific emissions			0.390	0.74	2.16	11.78	11.66	0.25
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

UP #9724 Test Date 12-03-98 CARB Diesel Fuel EM-2663-F Run #2/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	25	42.0	285	326	838	829	56
Low Idle	12	21.4	308	251	242	240	51
Idle	12	28.0	204	227	565	559	42
N1	197	82.3	154	147	1,673	1,656	75
N2	497	186.9	233	447	4,637	4,590	157
N3	1,037	390.6	400	1,737	12,517	12,389	245
N4	1,548	565.5	428	4,320	19,027	18,824	343
N5	2,227	780.0	661	4,936	29,510	29,202	369
N6	2,943	987.0	842	4,911	36,749	36,329	332
N7	3,662	1,209.5	1,013	4,029	43,674	43,164	312
N8	4,501	1,497.0	1,277	3,565	47,646	47,094	382
						sum =	

Weighted Results

Notch	EPA Line-Haul WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	3.1	5.3	35.6	40.8	104.8	103.7	7.0
Low Idle	19.0%	2.3	4.1	58.5	47.7	46.0	45.5	9.7
Idle	19.0%	2.3	5.3	38.8	43.1	107.4	106.2	8.0
N1	6.5%	12.8	5.3	10.0	9.6	108.7	107.7	4.9
N2	6.5%	32.3	12.1	15.1	29.1	301.4	298.3	10.2
N3	5.2%	53.9	20.3	20.8	90.3	650.9	644.2	12.7
N4	4.4%	68.1	24.9	18.8	190.1	837.2	828.3	15.1
N5	3.8%	84.6	29.6	25.1	187.6	1121.4	1109.7	14.0
N6	3.9%	114.8	38.5	32.8	191.5	1433.2	1416.8	12.9
N7	3.0%	109.9	36.3	30.4	120.9	1310.2	1294.9	9.4
N8	16.2%	729.2	242.5	206.9	577.5	7718.7	7629.3	61.9
TOTAL	100.0%	1213.3	424.3	492.9	1528.1	13739.8	13584.7	165.8
EPA line-haul duty cycle weighted brake-specific emissions			0.350	0.41	1.3	**11.3**	**11.2**	0.14
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	1.680	11.40	13.04	33.52	33.18	2.24
Low Idle	1.783	25.67	20.92	20.17	19.97	4.25
Idle	2.333	17.00	18.92	47.08	46.59	3.50
N1	0.418	0.78	0.75	8.49	8.41	0.38
N2	0.376	0.47	0.90	9.33	9.24	0.32
N3	0.377	0.39	1.68	12.07	11.95	0.24
N4	0.365	0.28	2.79	12.29	12.16	0.22
N5	0.350	0.30	2.22	13.25	13.11	0.17
N6	0.335	0.29	1.67	12.49	12.34	0.11
N7	0.330	0.28	1.10	11.93	11.79	0.09
N8	0.333	0.28	0.79	10.59	10.46	0.08

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	3.6	6.4	92.1	75.0	72.4	71.7	15.2
Idle	29.9%	3.6	8.4	61.0	67.9	168.9	167.2	12.6
N1	12.4%	24.4	10.2	19.1	18.2	207.5	205.4	9.3
N2	12.3%	61.1	23.0	28.7	55.0	570.4	564.6	19.3
N3	5.8%	60.1	22.7	23.2	100.7	726.0	718.6	14.2
N4	3.6%	55.7	20.4	15.4	155.5	685.0	677.7	12.3
N5	3.6%	80.2	28.1	23.8	177.7	1062.4	1051.3	13.3
N6	1.5%	44.1	14.8	12.6	73.7	551.2	544.9	5.0
N7	0.2%	7.3	2.4	2.0	8.1	87.3	86.3	0.6
N8	0.8%	36.0	12.0	10.2	28.5	381.2	376.8	3.1
TOTAL	100.0%	376.3	148.3	288.1	760.3	4512.2	4464.3	104.9
EPA switch duty cycle weighted brake-specific emissions			0.394	0.77	2.02	11.99	11.86	0.28
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

UP #9724 Test Date 12-04-98 CARB Diesel Fuel EM-2663-F Run #3/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	24	42.0	304	318	872	862	55
Low Idle	11	20.0	270	228	238	236	44
Idle	11	24.9	194	198	520	515	35
N1	195	79.0	135	141	1,661	1,644	73
N2	497	185.0	213	415	4,722	4,671	132
N3	1,035	389.5	418	1,730	12,386	12,260	221
N4	1,552	565.7	422	4,726	18,552	18,365	319
N5	2,224	780.0	648	5,463	28,512	28,224	344
N6	2,941	988.0	841	5,535	36,456	36,091	326
N7	3,659	1,213.2	1,024	4,993	42,276	41,873	340
N8	4,499	1,500.0	1,239	4,783	47,778	47,312	399
							sum =

Weighted Results

Notch	EPA Line-Haul WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	3.0	5.3	38.0	39.8	109.0	107.8	6.9
Low Idle	19.0%	2.1	3.8	51.3	43.3	45.2	44.9	8.4
Idle	19.0%	2.1	4.7	36.9	37.6	98.8	97.9	6.7
N1	6.5%	12.7	5.1	8.8	9.2	108.0	106.9	4.7
N2	6.5%	32.3	12.0	13.8	27.0	306.9	303.6	8.6
N3	5.2%	53.8	20.3	21.7	90.0	644.1	637.5	11.5
N4	4.4%	68.3	24.9	18.6	207.9	816.3	808.1	14.0
N5	3.8%	84.5	29.6	24.6	207.6	1083.5	1072.5	13.1
N6	3.9%	114.7	38.5	32.8	215.9	1421.8	1407.5	12.7
N7	3.0%	109.8	36.4	30.7	149.8	1268.3	1256.2	10.2
N8	16.2%	728.8	243.0	200.7	774.8	7740.0	7664.5	64.6
TOTAL	100.0%	1212.1	423.7	477.9	1802.8	13641.8	13507.4	161.4
EPA line-haul duty cycle weighted brake-specific emissions			0.350	0.39	1.5	**11.3**	**11.1**	0.13
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	1.750	12.67	13.25	36.33	35.93	2.29
Low Idle	1.818	24.55	20.73	21.64	21.46	4.00
Idle	2.264	17.64	18.00	47.27	46.85	3.18
N1	0.405	0.69	0.72	8.52	8.43	0.37
N2	0.372	0.43	0.84	9.50	9.40	0.27
N3	0.376	0.40	1.67	11.97	11.85	0.21
N4	0.364	0.27	3.05	11.95	11.83	0.21
N5	0.351	0.29	2.46	12.82	12.69	0.15
N6	0.336	0.29	1.88	12.40	12.27	0.11
N7	0.332	0.28	1.36	11.55	11.44	0.09
N8	0.333	0.28	1.06	10.62	10.52	0.09

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	3.3	6.0	80.7	68.2	71.2	70.6	13.2
Idle	29.9%	3.3	7.4	58.0	59.2	155.5	154.1	10.5
N1	12.4%	24.2	9.8	16.7	17.5	206.0	203.9	9.1
N2	12.3%	61.1	22.8	26.2	51.0	580.8	574.6	16.2
N3	5.8%	60.0	22.6	24.2	100.3	718.4	711.1	12.8
N4	3.6%	55.9	20.4	15.2	170.1	667.9	661.2	11.5
N5	3.6%	80.1	28.1	23.3	196.7	1026.4	1016.1	12.4
N6	1.5%	44.1	14.8	12.6	83.0	546.8	541.4	4.9
N7	0.2%	7.3	2.4	2.0	10.0	84.6	83.7	0.7
N8	0.8%	36.0	12.0	9.9	38.3	382.2	378.5	3.2
TOTAL	100.0%	375.3	146.3	269.0	794.3	4439.7	4395.0	94.4
EPA switch duty cycle weighted brake-specific emissions			0.390	0.72	2.12	11.83	11.71	0.25
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

APPENDIX D-3

UP No. 9724 Test Results Using On-Highway Diesel Fuel

UP #9724 Test Date 11-29-98 On-Highway Diesel Fuel EM-2677-F Run #1/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	26	46.5	337	391	1011	1,002	75
Low Idle	14	21.0	268	237	267	265	51
Idle	14	24.8	194	234	550	545	33
N1	196	82.0	141	146	1,817	1,802	88
N2	500	189.0	242	449	4,952	4,911	165
N3	1,041	394.0	391	1,705	13,310	13,205	224
N4	1,550	569.0	385	4,186	19,349	19,208	284
N5	2,223	789.0	612	5,891	29,866	29,647	332
N6	2,941	1,003.0	822	6,438	37,091	36,815	362
N7	3,660	1,221.0	1,094	4,858	44,239	43,902	382
N8	4,499	1,514.0	1,357	4,552	48,482	47,848	450
							sum =

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	3.3	5.8	42.1	48.9	126.4	125.2	9.4
Low Idle	19.0%	2.7	4.0	50.9	45.0	50.7	50.4	9.7
Idle	19.0%	2.7	4.7	36.9	44.5	104.5	103.5	6.3
N1	6.5%	12.7	5.3	9.2	9.5	118.1	117.1	5.7
N2	6.5%	32.5	12.3	15.7	29.2	321.9	319.2	10.7
N3	5.2%	54.1	20.5	20.3	88.7	692.1	686.7	11.6
N4	4.4%	68.2	25.0	16.9	184.2	851.4	845.1	12.5
N5	3.8%	84.5	30.0	23.3	223.9	1134.9	1126.6	12.6
N6	3.9%	114.7	39.1	32.1	251.1	1446.5	1435.8	14.1
N7	3.0%	109.8	36.6	32.8	145.7	1327.2	1317.1	11.5
N8	16.2%	728.8	245.3	219.8	737.4	7854.1	7751.4	72.9
TOTAL	100.0%	1214.0	428.7	500.0	1808.0	14027.8	13878.1	177.0
EPA line-haul duty cycle weighted brake-specific emissions			0.353	0.41	1.5	**11.6**	**11.4**	0.15
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

EPA Switch Cycle

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	1.788	12.96	15.04	38.88	38.53	2.88
Low Idle	1.500	19.14	16.93	19.07	18.94	3.64
Idle	1.771	13.86	16.71	39.29	38.92	2.36
N1	0.418	0.72	0.74	9.27	9.19	0.45
N2	0.378	0.48	0.90	9.90	9.82	0.33
N3	0.378	0.38	1.64	12.79	12.69	0.22
N4	0.367	0.25	2.70	12.48	12.39	0.18
N5	0.355	0.28	2.65	13.43	13.34	0.15
N6	0.341	0.28	2.19	12.61	12.52	0.12
N7	0.334	0.30	1.33	12.09	12.00	0.10
N8	0.337	0.30	1.01	10.78	10.64	0.10

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	4.2	6.3	80.1	70.9	79.8	79.3	15.2
Idle	29.9%	4.2	7.4	58.0	70.0	164.5	162.9	9.9
N1	12.4%	24.3	10.2	17.5	18.1	225.3	223.4	10.9
N2	12.3%	61.5	23.2	29.8	55.2	609.1	604.0	20.3
N3	5.8%	60.4	22.9	22.7	98.9	772.0	765.9	13.0
N4	3.6%	55.8	20.5	13.9	150.7	696.6	691.5	10.2
N5	3.6%	80.0	28.4	22.0	212.1	1075.2	1067.3	12.0
N6	1.5%	44.1	15.0	12.3	96.6	556.4	552.2	5.4
N7	0.2%	7.3	2.4	2.2	9.7	88.5	87.8	0.8
N8	0.8%	36.0	12.1	10.9	36.4	387.9	382.8	3.6
TOTAL	100.0%	377.8	148.4	269.3	818.5	4655.1	4617.2	101.3
EPA switch duty cycle weighted brake-specific emissions			0.393	0.71	2.17	12.32	12.22	0.27
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

UP #9724 Test Date 12-1-98 On-Highway Diesel Fuel EM-2677-F Run #2/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	23	41.5	328	428	923	917	79
Low Idle	12	22.3	379	303	282	281	63
Idle	12	27.0	214	289	617	613	39
N1	197	83.4	165	159	1,935	1,924	108
N2	495	188.4	249	414	5,074	5,047	207
N3	1,032	393.0	420	1,452	13,516	13,452	249
N4	1,549	568.0	476	3,570	20,069	19,965	303
N5	2,223	784.5	677	4,462	30,682	30,523	314
N6	2,942	993.8	810	4,726	37,791	37,618	313
N7	3,663	1,215.8	1,049	3,757	44,999	44,785	336
N8	4,490	1,504.5	1,357	3,537	51,711	51,459	393
						sum =	

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.9	5.2	41.0	53.5	115.4	114.7	9.9
Low Idle	19.0%	2.3	4.2	72.0	57.6	53.6	53.3	12.0
Idle	19.0%	2.3	5.1	40.7	54.9	117.2	116.5	7.4
N1	6.5%	12.8	5.4	10.7	10.3	125.8	125.1	7.0
N2	6.5%	32.2	12.2	16.2	26.9	329.8	328.1	13.5
N3	5.2%	53.7	20.4	21.8	75.5	702.8	699.5	12.9
N4	4.4%	68.2	25.0	20.9	157.1	883.0	878.5	13.3
N5	3.8%	84.5	29.8	25.7	169.6	1165.9	1159.9	11.9
N6	3.9%	114.7	38.8	31.6	184.3	1473.8	1467.1	12.2
N7	3.0%	109.9	36.5	31.5	112.7	1350.0	1343.5	10.1
N8	16.2%	727.4	243.7	219.8	573.0	8377.2	8336.3	63.7
TOTAL	100.0%	1210.7	426.4	532.0	1475.4	14694.6	14622.4	173.9
EPA line-haul duty cycle weighted brake-specific emissions			0.352	0.44	1.2	**12.1**	**12.1**	0.14
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	1.804	14.26	18.61	40.13	39.89	3.43
Low Idle	1.858	31.58	25.25	23.50	23.39	5.25
Idle	2.250	17.83	24.08	51.42	51.09	3.25
N1	0.423	0.84	0.81	9.82	9.77	0.55
N2	0.381	0.50	0.84	10.25	10.20	0.42
N3	0.381	0.41	1.41	13.10	13.03	0.24
N4	0.367	0.31	2.30	12.96	12.89	0.20
N5	0.353	0.30	2.01	13.80	13.73	0.14
N6	0.338	0.28	1.61	12.85	12.79	0.11
N7	0.332	0.29	1.03	12.28	12.23	0.09
N8	0.335	0.30	0.79	11.52	11.46	0.09

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	3.6	6.7	113.3	90.6	84.3	83.9	18.8
Idle	29.9%	3.6	8.1	64.0	86.4	184.5	183.3	11.7
N1	12.4%	24.4	10.3	20.5	19.7	239.9	238.6	13.4
N2	12.3%	60.9	23.2	30.6	50.9	624.1	620.8	25.5
N3	5.8%	59.9	22.8	24.4	84.2	783.9	780.2	14.4
N4	3.6%	55.8	20.4	17.1	128.5	722.5	718.8	10.9
N5	3.6%	80.0	28.2	24.4	160.6	1104.6	1098.8	11.3
N6	1.5%	44.1	14.9	12.2	70.9	566.9	564.3	4.7
N7	0.2%	7.3	2.4	2.1	7.5	90.0	89.6	0.7
N8	0.8%	35.9	12.0	10.9	28.3	413.7	411.7	3.1
TOTAL	100.0%	375.5	149.1	319.4	727.7	4814.4	4790.0	114.5
EPA switch duty cycle weighted brake-specific emissions			0.397	0.85	1.94	12.82	12.76	0.30
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

UP #9724 Test Date 12-03-98 On-Highway Diesel Fuel EM-2677-F Run #3/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	33	44.0	360	366	940	930	57
Low Idle	16	22.0	309	243	285	282	53
Idle	16	26.0	223	223	555	550	35
N1	196	81.0	150	143	1,779	1,762	65
N2	496	188.0	226	428	4,970	4,924	118
N3	1,034	392.0	486	1,713	13,170	13,049	217
N4	1,555	569.0	499	5,054	22,335	22,114	282
N5	2,224	784.0	645	5,171	29,822	29,537	292
N6	2,946	994.0	910	5,355	38,472	38,105	329
N7	3,662	1,220.0	1,086	4,381	44,515	44,067	349
N8	4,498	1,509.0	1,337	4,071	49,114	48,593	403
							sum =

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	4.1	5.5	45.0	45.8	117.5	116.3	7.1
Low Idle	19.0%	3.0	4.2	58.7	46.2	54.2	53.6	10.1
Idle	19.0%	3.0	4.9	42.4	42.4	105.5	104.4	6.7
N1	6.5%	12.7	5.3	9.8	9.3	115.6	114.5	4.2
N2	6.5%	32.2	12.2	14.7	27.8	323.1	320.1	7.7
N3	5.2%	53.8	20.4	25.3	89.1	684.8	678.6	11.3
N4	4.4%	68.4	25.0	22.0	222.4	982.7	973.0	12.4
N5	3.8%	84.5	29.8	24.5	196.5	1133.2	1122.4	11.1
N6	3.9%	114.9	38.8	35.5	208.8	1500.4	1486.1	12.8
N7	3.0%	109.9	36.6	32.6	131.4	1335.5	1322.0	10.5
N8	16.2%	728.7	244.5	216.6	659.5	7956.5	7872.1	65.3
TOTAL	100.0%	1215.3	427.1	526.9	1679.1	14308.9	14163.0	159.1
EPA line-haul duty cycle weighted brake-specific emissions			0.351	0.43	1.4	**11.8**	**11.7**	0.13
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	1.333	10.91	11.09	28.48	28.18	1.73
Low Idle	1.375	19.31	15.19	17.81	17.64	3.31
Idle	1.625	13.94	13.94	34.69	34.35	2.19
N1	0.413	0.77	0.73	9.08	8.99	0.33
N2	0.379	0.46	0.86	10.02	9.93	0.24
N3	0.379	0.47	1.66	12.74	12.62	0.21
N4	0.366	0.32	3.25	14.36	14.22	0.18
N5	0.353	0.29	2.33	13.41	13.28	0.13
N6	0.337	0.31	1.82	13.06	12.93	0.11
N7	0.333	0.30	1.20	12.16	12.03	0.10
N8	0.335	0.30	0.91	10.92	10.80	0.09

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	4.8	6.6	92.4	72.7	85.2	84.4	15.8
Idle	29.9%	4.8	7.8	66.7	66.7	165.9	164.3	10.5
N1	12.4%	24.3	10.0	18.6	17.7	220.6	218.5	8.1
N2	12.3%	61.0	23.1	27.8	52.6	611.3	605.6	14.5
N3	5.8%	60.0	22.7	28.2	99.4	763.9	756.9	12.6
N4	3.6%	56.0	20.5	18.0	181.9	804.1	796.1	10.2
N5	3.6%	80.1	28.2	23.2	186.2	1073.6	1063.3	10.5
N6	1.5%	44.2	14.9	13.7	80.3	577.1	571.6	4.9
N7	0.2%	7.3	2.4	2.2	8.8	89.0	88.1	0.7
N8	0.8%	36.0	12.1	10.7	32.6	392.9	388.7	3.2
TOTAL	100.0%	378.4	148.4	301.4	798.8	4783.6	4737.6	91.0
EPA switch duty cycle weighted brake-specific emissions			0.392	0.80	2.11	12.64	12.52	0.24
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

APPENDIX D-4

UP No. 9724 Test Results Using High-Sulfur Diesel Fuel

UP #9724 Test Date 11-30-98 Nonroad High-Sulfur Diesel Fuel EM-2664-F Run #1/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	26	39.8	289	338	854	841	72
Low Idle	13	22.7	283	279	267	263	60
Idle	12	28.3	218	257	625	616	53
N1	194	80.4	145	136	1,991	1,963	88
N2	498	187.2	255	400	5,179	5,104	167
N3	1,035	394.0	474	1,485	14,024	13,802	261
N4	1,548	573.0	448	3,962	20,088	19,755	355
N5	2,225	787.2	644	4,566	31,466	30,985	415
N6	2,942	998.0	817	5,308	39,221	38,604	503
N7	3,662	1,220.4	1,081	4,248	46,251	45,540	592
N8	4,500	1,509.6	1,255	3,828	51,758	50,925	850
						sum =	

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	3.3	5.0	36.1	42.3	106.8	105.2	9.0
Low Idle	19.0%	2.5	4.3	53.8	53.0	50.7	49.9	11.4
Idle	19.0%	2.3	5.4	41.4	48.8	118.8	117.0	10.1
N1	6.5%	12.6	5.2	9.4	8.8	129.4	127.6	5.7
N2	6.5%	32.4	12.2	16.6	26.0	336.6	331.8	10.9
N3	5.2%	53.8	20.5	24.6	77.2	729.2	717.7	13.6
N4	4.4%	68.1	25.2	19.7	174.3	883.9	869.2	15.6
N5	3.8%	84.6	29.9	24.5	173.5	1195.7	1177.4	15.8
N6	3.9%	114.7	38.9	31.9	207.0	1529.6	1505.5	19.6
N7	3.0%	109.9	36.6	32.4	127.4	1387.5	1366.2	17.8
N8	16.2%	729.0	244.6	203.3	620.1	8384.8	8249.9	137.7
TOTAL	100.0%	1213.1	427.8	493.8	1558.6	14853.1	14617.5	267.1
EPA line-haul duty cycle weighted brake-specific emissions			0.353	0.41	1.3	**12.2**	**12.1**	0.22
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	1.531	11.12	13.00	32.85	32.36	2.77
Low Idle	1.746	21.77	21.46	20.54	20.22	4.62
Idle	2.358	18.17	21.42	52.08	51.32	4.42
N1	0.414	0.75	0.70	10.26	10.12	0.45
N2	0.376	0.51	0.80	10.40	10.25	0.34
N3	0.381	0.46	1.43	13.55	13.34	0.25
N4	0.370	0.29	2.56	12.98	12.76	0.23
N5	0.354	0.29	2.05	14.14	13.93	0.19
N6	0.339	0.28	1.80	13.33	13.12	0.17
N7	0.333	0.30	1.16	12.63	12.44	0.16
N8	0.335	0.28	0.85	11.50	11.32	0.19

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	3.9	6.8	84.6	83.4	79.8	78.6	17.9
Idle	29.9%	3.6	8.5	65.2	76.8	186.9	184.1	15.8
N1	12.4%	24.1	10.0	18.0	16.9	246.9	243.4	10.9
N2	12.3%	61.3	23.0	31.4	49.2	637.0	627.8	20.5
N3	5.8%	60.0	22.9	27.5	86.1	813.4	800.5	15.1
N4	3.6%	55.7	20.6	16.1	142.6	723.2	711.2	12.8
N5	3.6%	80.1	28.3	23.2	164.4	1132.8	1115.4	14.9
N6	1.5%	44.1	15.0	12.3	79.6	588.3	579.1	7.5
N7	0.2%	7.3	2.4	2.2	8.5	92.5	91.1	1.2
N8	0.8%	36.0	12.1	10.0	30.6	414.1	407.4	6.8
TOTAL	100.0%	376.1	149.6	290.4	738.2	4914.8	4838.7	123.6
EPA switch duty cycle weighted brake-specific emissions			0.398	0.77	1.96	13.07	12.87	0.33
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

UP #9724 Test Date 12-1-98 Nonroad High-Sulfur Diesel Fuel EM-2664-F Run #2/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	33	47.3	356	411	1,013	1,009	89
Low Idle	16	22.0	286	259	245	244	61
Idle	12	25.6	202	222	554	552	47
N1	193	82.3	143	146	2,012	2,003	81
N2	498	188.4	260	428	5,206	5,187	159
N3	1,033	396.0	460	1,585	13,829	13,775	279
N4	1,548	568.5	467	3,971	20,018	19,943	385
N5	2,225	789.6	635	4,491	31,592	31,481	432
N6	2,939	993.6	800	5,230	38,633	38,504	480
N7	3,662	1,218.0	1,011	5,264	46,990	46,848	604
N8	4,502	1,501.2	1,323	3,753	53,305	53,127	762
						sum =	

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	4.1	5.9	44.5	51.4	126.6	126.1	11.1
Low Idle	19.0%	3.0	4.2	54.3	49.2	46.6	46.3	11.6
Idle	19.0%	2.3	4.9	38.4	42.2	105.3	104.8	8.9
N1	6.5%	12.5	5.3	9.3	9.5	130.8	130.2	5.3
N2	6.5%	32.4	12.2	16.9	27.8	338.4	337.2	10.3
N3	5.2%	53.7	20.6	23.9	82.4	719.1	716.3	14.5
N4	4.4%	68.1	25.0	20.5	174.7	880.8	877.5	16.9
N5	3.8%	84.6	30.0	24.1	170.7	1200.5	1196.3	16.4
N6	3.9%	114.6	38.8	31.2	204.0	1506.7	1501.6	18.7
N7	3.0%	109.9	36.5	30.3	157.9	1409.7	1405.5	18.1
N8	16.2%	729.3	243.2	214.3	608.0	8635.4	8606.5	123.4
TOTAL	100.0%	1214.5	426.6	507.9	1577.8	15099.8	15048.2	255.4
EPA line-haul duty cycle weighted brake-specific emissions			0.351	0.42	1.3	**12.4**	**12.4**	0.21
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	1.433	10.79	12.45	30.70	30.56	2.70
Low Idle	1.375	17.88	16.19	15.31	15.22	3.81
Idle	2.133	16.83	18.50	46.17	45.98	3.92
N1	0.426	0.74	0.76	10.42	10.38	0.42
N2	0.378	0.52	0.86	10.45	10.42	0.32
N3	0.383	0.45	1.53	13.39	13.33	0.27
N4	0.367	0.30	2.57	12.93	12.88	0.25
N5	0.355	0.29	2.02	14.20	14.15	0.19
N6	0.338	0.27	1.78	13.14	13.10	0.16
N7	0.333	0.28	1.44	12.83	12.79	0.16
N8	0.333	0.29	0.83	11.84	11.80	0.17

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	4.8	6.6	85.5	77.4	73.3	72.8	18.2
Idle	29.9%	3.6	7.7	60.4	66.4	165.6	165.0	14.1
N1	12.4%	23.9	10.2	17.7	18.1	249.5	248.4	10.0
N2	12.3%	61.3	23.2	32.0	52.6	640.3	638.0	19.6
N3	5.8%	59.9	23.0	26.7	91.9	802.1	798.9	16.2
N4	3.6%	55.7	20.5	16.8	143.0	720.6	717.9	13.9
N5	3.6%	80.1	28.4	22.9	161.7	1137.3	1133.3	15.6
N6	1.5%	44.1	14.9	12.0	78.5	579.5	577.6	7.2
N7	0.2%	7.3	2.4	2.0	10.5	94.0	93.7	1.2
N8	0.8%	36.0	12.0	10.6	30.0	426.4	425.0	6.1
TOTAL	100.0%	376.7	148.8	286.6	730.1	4888.7	4870.7	122.0
EPA switch duty cycle weighted brake-specific emissions			0.395	0.76	1.94	12.98	12.93	0.32
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

UP #9724 Test Date 12-02-98 Nonroad High-Sulfur Diesel Fuel EM-2664-F Runb #3/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	25	48.9	377	498	1,024	1,014	96
Low Idle	11	17.3	182	201	261	259	40
Idle	12	27.0	193	257	583	579	42
N1	199	82.7	141	147	2,078	2,065	70
N2	496	193.1	226	435	5,284	5,253	160
N3	1,035	401.3	406	1,842	13,947	13,865	345
N4	1,551	578.9	404	4,665	20,286	20,173	458
N5	2,226	798.8	550	5,895	30,989	30,835	509
N6	2,942	1,011.0	756	6,476	38,512	38,353	575
N7	3,660	1,227.8	930	4,921	46,137	45,995	754
N8	4,501	1,521.3	1,140	4,105	52,128	52,025	956
							sum =

Weighted Results

Notch	EPA Line-Haul WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	3.1	6.1	47.1	62.3	128.0	126.7	12.0
Low Idle	19.0%	2.1	3.3	34.6	38.2	49.6	49.2	7.6
Idle	19.0%	2.3	5.1	36.7	48.8	110.8	110.0	8.0
N1	6.5%	12.9	5.4	9.2	9.6	135.1	134.2	4.6
N2	6.5%	32.2	12.6	14.7	28.3	343.5	341.5	10.4
N3	5.2%	53.8	20.9	21.1	95.8	725.2	721.0	17.9
N4	4.4%	68.2	25.5	17.8	205.3	892.6	887.6	20.2
N5	3.8%	84.6	30.4	20.9	224.0	1177.6	1171.7	19.3
N6	3.9%	114.7	39.4	29.5	252.6	1502.0	1495.8	22.4
N7	3.0%	109.8	36.8	27.9	147.6	1384.1	1379.9	22.6
N8	16.2%	729.2	246.5	184.7	665.0	8444.7	8428.1	154.9
TOTAL	100.0%	1213.0	431.9	444.1	1777.4	14893.1	14845.6	299.9
EPA line-haul duty cycle weighted brake-specific emissions			0.356	0.37	1.5	**12.3**	**12.2**	0.25
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

EPA Switch Cycle

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	1.956	15.08	19.92	40.96	40.55	3.84
Low Idle	1.573	16.55	18.27	23.73	23.52	3.64
Idle	2.250	16.08	21.42	48.58	48.26	3.50
N1	0.416	0.71	0.74	10.44	10.38	0.35
N2	0.389	0.46	0.88	10.65	10.59	0.32
N3	0.388	0.39	1.78	13.48	13.40	0.33
N4	0.373	0.26	3.01	13.08	13.01	0.30
N5	0.359	0.25	2.65	13.92	13.85	0.23
N6	0.344	0.26	2.20	13.09	13.04	0.20
N7	0.335	0.25	1.34	12.61	12.57	0.21
N8	0.338	0.25	0.91	11.58	11.56	0.21

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	3.3	5.2	54.4	60.1	78.0	77.4	12.0
Idle	29.9%	3.6	8.1	57.7	76.8	174.3	173.1	12.6
N1	12.4%	24.7	10.3	17.5	18.2	257.7	256.1	8.7
N2	12.3%	61.0	23.8	27.8	53.5	649.9	646.1	19.7
N3	5.8%	60.0	23.3	23.5	106.8	808.9	804.2	20.0
N4	3.6%	55.8	20.8	14.5	167.9	730.3	726.2	16.5
N5	3.6%	80.1	28.8	19.8	212.2	1115.6	1110.1	18.3
N6	1.5%	44.1	15.2	11.3	97.1	577.7	575.3	8.6
N7	0.2%	7.3	2.5	1.9	9.8	92.3	92.0	1.5
N8	0.8%	36.0	12.2	9.1	32.8	417.0	416.2	7.6
TOTAL	100.0%	376.0	149.9	237.6	835.5	4901.8	4876.7	125.5
EPA switch duty cycle weighted brake-specific emissions			0.399	0.63	2.22	13.04	12.97	0.33
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

APPENDIX D-5

UP No. 9724 Test Results Using 0.3% Sulfur Diesel Fuel

UP #9724 Test Date 11-30-98 0.3% Sulfur Diesel Fuel EM-2708-F Run #1/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	25	38.0	306	358	810	796	100
Low Idle	13	22.0	328	283	255	250	75
Idle	12	28.5	245	272	616	606	54
N1	195	80.0	157	146	1,955	1,926	121
N2	496	189.4	262	398	5,242	5,170	209
N3	1,036	398.0	470	1,602	13,703	13,520	310
N4	1,548	572.4	407	3,922	20,216	19,947	363
N5	2,222	791.0	613	4,681	31,089	30,666	411
N6	2,942	1,002.0	813	5,386	38,517	37,969	456
N7	3,660	1,224.0	1,007	4,152	46,587	45,977	498
N8	4,499	1,512.0	1,288	3,615	51,648	51,009	640
						sum =	

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	3.1	4.8	38.3	44.8	101.3	99.5	12.5
Low Idle	19.0%	2.5	4.2	62.3	53.8	48.5	47.6	14.3
Idle	19.0%	2.3	5.4	46.6	51.7	117.0	115.1	10.3
N1	6.5%	12.7	5.2	10.2	9.5	127.1	125.2	7.9
N2	6.5%	32.2	12.3	17.0	25.9	340.7	336.0	13.6
N3	5.2%	53.9	20.7	24.4	83.3	712.6	703.1	16.1
N4	4.4%	68.1	25.2	17.9	172.6	889.5	877.7	16.0
N5	3.8%	84.4	30.1	23.3	177.9	1181.4	1165.3	15.6
N6	3.9%	114.7	39.1	31.7	210.1	1502.2	1480.8	17.8
N7	3.0%	109.8	36.7	30.2	124.6	1397.6	1379.3	14.9
N8	16.2%	728.8	244.9	208.7	585.6	8367.0	8263.4	103.7
TOTAL	100.0%	1212.6	428.5	510.6	1539.6	14784.7	14592.9	242.6
EPA line-haul duty cycle weighted brake-specific emissions			0.353	0.42	1.3	**12.2**	**12.0**	0.20
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	1.520	12.24	14.32	32.40	31.83	4.00
Low Idle	1.692	25.23	21.77	19.62	19.25	5.77
Idle	2.375	20.42	22.67	51.33	50.50	4.50
N1	0.410	0.81	0.75	10.03	9.88	0.62
N2	0.382	0.53	0.80	10.57	10.42	0.42
N3	0.384	0.45	1.55	13.23	13.05	0.30
N4	0.370	0.26	2.53	13.06	12.89	0.23
N5	0.356	0.28	2.11	13.99	13.80	0.18
N6	0.341	0.28	1.83	13.09	12.91	0.15
N7	0.334	0.28	1.13	12.73	12.56	0.14
N8	0.336	0.29	0.80	11.48	11.34	0.14

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	3.9	6.6	98.1	84.6	76.2	74.8	22.4
Idle	29.9%	3.6	8.5	73.3	81.3	184.2	181.2	16.1
N1	12.4%	24.2	9.9	19.5	18.1	242.4	238.8	15.0
N2	12.3%	61.0	23.3	32.2	49.0	644.8	635.9	25.7
N3	5.8%	60.1	23.1	27.3	92.9	794.8	784.2	18.0
N4	3.6%	55.7	20.6	14.7	141.2	727.8	718.1	13.1
N5	3.6%	80.0	28.5	22.1	168.5	1119.2	1104.0	14.8
N6	1.5%	44.1	15.0	12.2	80.8	577.8	569.5	6.8
N7	0.2%	7.3	2.4	2.0	8.3	93.2	92.0	1.0
N8	0.8%	36.0	12.1	10.3	28.9	413.2	408.1	5.1
TOTAL	100.0%	375.9	150.1	311.5	753.6	4873.5	4806.5	138.1
EPA switch duty cycle weighted brake-specific emissions			0.399	0.83	2.00	12.96	12.79	0.37
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

UP #9724 Test Date 12-02-98 0.3% Sulfur Diesel Fuel EM-2708-F Run #2/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	33	44.3	348	394	1,007	1,007	69
Low Idle	12	19.5	276	241	233	233	49
Idle	12	27.0	230	262	600	599	44
N1	194	80.6	149	143	1,963	1,963	74
N2	496	188.0	229	406	4,815	4,811	149
N3	1,034	394.5	436	1,625	13,801	13,787	292
N4	1,554	569.3	414	4,530	20,377	20,355	357
N5	2,221	790.5	640	5,240	30,719	30,687	434
N6	2,943	1,000.5	794	5,611	38,424	38,362	484
N7	3,661	1,222.7	1,039	4,364	38,880	38,862	491
N8	4,500	1,513.3	1,232	4,116	50,518	50,455	655
							sum =

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	4.1	5.5	43.5	49.3	125.9	125.8	8.6
Low Idle	19.0%	2.3	3.7	52.4	45.8	44.3	44.3	9.3
Idle	19.0%	2.3	5.1	43.7	49.8	114.0	113.9	8.4
N1	6.5%	12.6	5.2	9.7	9.3	127.6	127.6	4.8
N2	6.5%	32.2	12.2	14.9	26.4	313.0	312.7	9.7
N3	5.2%	53.8	20.5	22.7	84.5	717.7	716.9	15.2
N4	4.4%	68.4	25.0	18.2	199.3	896.6	895.6	15.7
N5	3.8%	84.4	30.0	24.3	199.1	1167.3	1166.1	16.5
N6	3.9%	114.8	39.0	31.0	218.8	1498.5	1496.1	18.9
N7	3.0%	109.8	36.7	31.2	130.9	1166.4	1165.9	14.7
N8	16.2%	729.0	245.2	199.6	666.8	8183.9	8173.7	106.1
TOTAL	100.0%	1213.7	428.3	491.1	1680.0	14355.1	14338.6	227.9
EPA line-haul duty cycle weighted brake-specific emissions			0.353	0.40	1.4	**11.8**	**11.8**	0.19
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	1.342	10.55	11.94	30.52	30.50	2.09
Low Idle	1.625	23.00	20.08	19.42	19.42	4.08
Idle	2.250	19.17	21.83	50.00	49.94	3.67
N1	0.415	0.77	0.74	10.12	10.12	0.38
N2	0.379	0.46	0.82	9.71	9.70	0.30
N3	0.382	0.42	1.57	13.35	13.33	0.28
N4	0.366	0.27	2.92	13.11	13.10	0.23
N5	0.356	0.29	2.36	13.83	13.82	0.20
N6	0.340	0.27	1.91	13.06	13.04	0.16
N7	0.334	0.28	1.19	10.62	10.62	0.13
N8	0.336	0.27	0.91	11.23	11.21	0.15

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	3.6	5.8	82.5	72.1	69.7	69.7	14.7
Idle	29.9%	3.6	8.1	68.8	78.3	179.4	179.2	13.2
N1	12.4%	24.1	10.0	18.5	17.7	243.4	243.4	9.2
N2	12.3%	61.0	23.1	28.2	49.9	592.2	591.7	18.3
N3	5.8%	60.0	22.9	25.3	94.3	800.5	799.6	16.9
N4	3.6%	55.9	20.5	14.9	163.1	733.6	732.8	12.9
N5	3.6%	80.0	28.5	23.0	188.6	1105.9	1104.7	15.6
N6	1.5%	44.1	15.0	11.9	84.2	576.4	575.4	7.3
N7	0.2%	7.3	2.4	2.1	8.7	77.8	77.7	1.0
N8	0.8%	36.0	12.1	9.9	32.9	404.1	403.6	5.2
TOTAL	100.0%	375.6	148.4	285.0	789.9	4782.9	4778.0	114.2
EPA switch duty cycle weighted brake-specific emissions			0.395	0.76	2.10	12.73	12.72	0.30
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

UP #9724 Test Date 12-04-98 0.3% Sulfur Diesel Diesel Fuel EM-2708-F Run #3/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	25	41.4	358	420	882	870	79
Low Idle	11	23.0	329	294	266	262	56
Idle	11	24.8	215	260	540	533	39
N1	197	79.7	151	141	1,960	1,935	80
N2	498	188.0	222	400	5,212	5,147	163
N3	1,038	394.8	499	1,683	14,213	14,039	251
N4	1,550	570.0	397	3,821	19,708	19,457	337
N5	2,225	790.3	609	5,148	31,519	31,140	387
N6	2,942	1,005.6	810	6,279	38,503	38,028	464
N7	3,661	1,223.0	1,004	5,317	45,152	44,583	544
N8	4,503	1,518.0	1,127	4,579	50,069	49,440	643
						sum =	

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	3.1	5.2	44.8	52.5	110.3	108.7	9.9
Low Idle	19.0%	2.1	4.4	62.5	55.9	50.5	49.8	10.6
Idle	19.0%	2.1	4.7	40.9	49.4	102.6	101.2	7.4
N1	6.5%	12.8	5.2	9.8	9.2	127.4	125.7	5.2
N2	6.5%	32.4	12.2	14.4	26.0	338.8	334.5	10.6
N3	5.2%	54.0	20.5	25.9	87.5	739.1	730.0	13.1
N4	4.4%	68.2	25.1	17.5	168.1	867.2	856.1	14.8
N5	3.8%	84.6	30.0	23.1	195.6	1197.7	1183.3	14.7
N6	3.9%	114.7	39.2	31.6	244.9	1501.6	1483.1	18.1
N7	3.0%	109.8	36.7	30.1	159.5	1354.6	1337.5	16.3
N8	16.2%	729.5	245.9	182.6	741.8	8111.2	8009.3	104.2
TOTAL	100.0%	1213.3	429.1	483.2	1790.4	14500.9	14319.4	224.9
EPA line-haul duty cycle weighted brake-specific emissions			0.354	0.40	1.5	**12.0**	**11.8**	0.19
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	1.656	14.32	16.80	35.28	34.80	3.16
Low Idle	2.091	29.91	26.73	24.18	23.85	5.09
Idle	2.255	19.55	23.64	49.09	48.43	3.55
N1	0.405	0.77	0.72	9.95	9.82	0.41
N2	0.378	0.45	0.80	10.47	10.33	0.33
N3	0.380	0.48	1.62	13.69	13.53	0.24
N4	0.368	0.26	2.47	12.71	12.55	0.22
N5	0.355	0.27	2.31	14.17	14.00	0.17
N6	0.342	0.28	2.13	13.09	12.93	0.16
N7	0.334	0.27	1.45	12.33	12.18	0.15
N8	0.337	0.25	1.02	11.12	10.98	0.14

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	3.3	6.9	98.4	87.9	79.5	78.4	16.7
Idle	29.9%	3.3	7.4	64.3	77.7	161.5	159.3	11.7
N1	12.4%	24.4	9.9	18.7	17.5	243.0	239.9	9.9
N2	12.3%	61.3	23.1	27.3	49.2	641.1	633.1	20.0
N3	5.8%	60.2	22.9	28.9	97.6	824.4	814.3	14.6
N4	3.6%	55.8	20.5	14.3	137.6	709.5	700.5	12.1
N5	3.6%	80.1	28.5	21.9	185.3	1134.7	1121.0	13.9
N6	1.5%	44.1	15.1	12.2	94.2	577.5	570.4	7.0
N7	0.2%	7.3	2.4	2.0	10.6	90.3	89.2	1.1
N8	0.8%	36.0	12.1	9.0	36.6	400.6	395.5	5.1
TOTAL	100.0%	375.8	148.8	297.0	794.3	4862.0	4801.5	112.2
EPA switch duty cycle weighted brake-specific emissions			0.396	0.79	2.11	12.94	12.78	0.30
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

APPENDIX D-6

UP No. 9724 Smoke Test Summary

SMOKE TEST SUMMARY FOR UP NO. 9724

Run #	**ss**	**30-sec**	**3-sec**
Carb Diesel (EM-2663-F)			
# 1	12	19	62
# 2	12	18	61
# 3	13	20	59
Avg	**12**	**19**	**61**
cov	5%	5%	3%
On-Highway Diesel (EM-2677-F)			
# 1	12	18	62
# 2	12	16	62
# 3	12	19	61
Avg	**12**	**18**	**62**
cov	0%	9%	1%
Nonroad High Sulfur Diesel (EM-2664-F)			
# 1	10	15	56
# 2	15	17	52
# 3	13	19	58
Avg	**13**	**17**	**55**
cov	20%	12%	6%
Fuel #4, Nonroad 0.3% Sulfur Diesel (EM-2708-F)			
# 1	12	14	57
# 2	12	15	61
# 3	10	15	56
Avg	**11**	**15**	**58**
cov	10%	4%	5%

updated 12/17/98 sgf

APPENDIX E-1

UP No. 9715 Test Summary

EPA Line-Haul Duty Cycle Weighting Factors

	obs bsfc	HC	CO	EPA NOx	KH-NOx	PM	UP 9715
	lb/hp-hr	g/hp-hr	g/hp-hr	g/hp-hr	g/hp-hr	g/hp-hr	GE DASH9-44CW
Carb Diesel (EM-2663-F)							updated 06-29-99
	0.353	0.32	2.8	10.842	10.751	0.13	
	0.357	0.35	2.8	10.672	10.571	0.13	
	0.357	0.31	3.0	10.405	10.340	0.12	
Avg	**0.356**	**0.327**	**2.87**	**10.640**	**10.554**	**0.126**	
cov	0.6%	5.2%	3.7%	2.1%	1.9%	4.4%	
On-Highway Diesel (EM-2677-F)							
	0.360	0.35	2.9	11.286	11.160	0.14	
	0.361	0.34	3.0	10.829	10.698	0.13	
	0.353	0.31	2.8	10.689	10.655	0.12	
Avg	**0.358**	**0.336**	**2.89**	**10.935**	**10.838**	**0.130**	
cov	1.2%	6.2%	3.8%	2.9%	2.6%	8.7%	
Nonroad High Sulfur Diesel (EM-2664-F)							
	0.359	0.33	3.0	11.790	11.646	0.20	
	0.361	0.31	3.3	11.518	11.354	0.24	
	0.361	0.33	2.6	11.411	11.384	0.20	
Avg	**0.361**	**0.324**	**3.00**	**11.573**	**11.462**	**0.213**	
cov	0.4%	3.6%	11.4%	1.7%	1.4%	11.9%	
0.3% Sulfur Diesel (EM-2708-F)							
	0.359	0.33	3.0	11.416	11.585	0.15	
	0.363	0.33	3.4	11.470	11.349	0.19	
	0.357	0.32	2.6	11.034	10.953	0.17	
Avg	**0.359**	**0.328**	**3.00**	**11.307**	**11.296**	**0.171**	
cov	0.9%	3.0%	13.5%	2.1%	2.8%	10.6%	
	-1.3%	1%	-4%	-8%	-8%	-41%	carb vs HS
	-0.7%	4%	-3%	-6%	-5%	-39%	on-hwy vs HS
	-0.6%	-3%	-1%	-3%	-2.6%	-2%	carb vs on-hwy

Note: EPA NOx = full NOx correction factor
Note: KH NOx = only ambient air humidity NOx correction factor applied

-1.0%	-0.1%	-4.2%	-5.9%	-6.6%	-25.9%	carb vs 0.3% S
-0.4%	2.6%	-3.5%	-3.3%	-4.1%	-24.1%	on-hwy vs 0.3% S

EPA Switcher Duty Cycle Weighting Factors

	obs bsfc	HC	CO	EPA NOx	KH-NOx	PM	
	lb/hp-hr	g/hp-hr	g/hp-hr	g/hp-hr	g/hp-hr	g/hp-hr	
Carb Diesel (EM-2663-F)							
	0.389	0.55	2.91	12.352	12.244	0.18	
	0.394	0.60	2.99	12.179	12.051	0.18	
	0.389	0.54	2.77	11.942	11.865	0.15	
Avg	**0.390**	**0.565**	**2.89**	12.158	12.053	**0.171**	
cov	0.7%	6.0%	3.8%	1.7%	1.6%	8.9%	
On-Highway Diesel (EM-2677-F)							
	0.396	0.62	3.03	13.102	12.943	0.17	
	0.396	0.62	3.03	12.778	12.616	0.17	
	0.388	0.56	2.60	12.671	12.641	0.15	
Avg	**0.393**	**0.601**	**2.89**	**12.850**	**12.733**	**0.165**	
cov	1.3%	5.7%	8.6%	1.7%	1.4%	6.3%	
Nonroad High Sulfur Diesel (EM-2664-F)							
	0.394	0.61	3.03	13.478	13.315	0.23	
	0.399	0.58	3.23	13.414	13.238	0.29	
	0.402	0.63	2.60	13.222	13.182	0.23	
Avg	**0.398**	**0.606**	**2.95**	**13.371**	**13.245**	**0.251**	
cov	1.0%	4.7%	10.8%	1.0%	0.5%	15.0%	
0.3% Sulfur Diesel (EM-2708-F)							
	0.397	0.64	3.02	13.327	13.285	0.18	
	0.402	0.65	3.24	13.817	13.662	0.22	
	0.393	0.57	2.48	12.817	12.723	0.20	
Avg	**0.397**	**0.621**	**2.92**	**13.320**	**13.223**	**0.200**	
cov	1.1%	7.2%	13.4%	3.8%	3.6%	9.1%	
	-2.0%	-7%	-2%	-9%	-9%	-32%	carb vs HS
	-1.3%	-1%	-2%	-4%	-4%	-34%	on-hwy vs HS
	-0.7%	-6%	0%	-5%	-5%	4%	carb vs on-hwy

APPENDIX E-2

UP No. 9715 Test Results Using CARB Diesel Fuel

UP #9715 Test Date 10-26-98 CARB Diesel Fuel EM-2663-F Run #1/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	32	40.8	200	358	830	823	30
Low Idle	13	20.6	156	189	397	392	22
Idle	12	24.0	147	236	492	489	19
N1	193	78.0	124	149	1,693	1,678	27
N2	495	183.0	188	314	4,720	4,681	55
N3	1,036	387.0	366	1,620	14,326	14,207	176
N4	1,550	558.0	384	5,681	20,865	20,677	300
N5	2,224	786.0	621	9,668	29,076	28,814	368
N6	2,939	996.3	726	10,077	34,737	34,425	353
N7	3,665	1,230.0	908	10,577	41,830	41,485	351
N8	4,489	1,527.6	1,060	11,461	43,654	43,295	492
						sum =	

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	4.0	5.1	25.0	44.8	103.8	102.9	3.8
Low Idle	19.0%	2.5	3.9	29.6	35.9	75.4	74.5	4.2
Idle	19.0%	2.3	4.6	27.9	44.8	93.5	92.8	3.6
N1	6.5%	12.5	5.1	8.1	9.7	110.0	109.1	1.8
N2	6.5%	32.2	11.9	12.2	20.4	306.8	304.2	3.6
N3	5.2%	53.9	20.1	19.0	84.2	745.0	738.8	9.2
N4	4.4%	68.2	24.6	16.9	250.0	918.1	909.8	13.2
N5	3.8%	84.5	29.9	23.6	367.4	1104.9	1094.9	14.0
N6	3.9%	114.6	38.9	28.3	393.0	1354.7	1342.6	13.8
N7	3.0%	110.0	36.9	27.2	317.3	1254.9	1244.5	10.5
N8	16.2%	727.2	247.5	171.7	1856.7	7071.9	7013.8	79.7
TOTAL	100.0%	1211.8	428.3	389.7	3424.2	13139.0	13028.0	157.2
EPA line-haul duty cycle weighted brake-specific emissions			0.353	0.32	2.8	**10.8**	**10.8**	0.13
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	1.275	6.25	11.19	25.94	25.73	0.94
Low Idle	1.585	12.00	14.54	30.54	30.18	1.69
Idle	2.000	12.25	19.67	41.00	40.71	1.58
N1	0.404	0.64	0.77	8.77	8.69	0.14
N2	0.370	0.38	0.63	9.54	9.46	0.11
N3	0.374	0.35	1.56	13.83	13.71	0.17
N4	0.360	0.25	3.67	13.46	13.34	0.19
N5	0.353	0.28	4.35	13.07	12.96	0.17
N6	0.339	0.25	3.43	11.82	11.71	0.12
N7	0.336	0.25	2.89	11.41	11.32	0.10
N8	0.340	0.24	2.55	9.72	9.64	0.11

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	3.9	6.2	46.6	56.5	118.7	117.3	6.6
Idle	29.9%	3.6	7.2	44.0	70.6	147.1	146.1	5.7
N1	12.4%	23.9	9.7	15.4	18.5	209.9	208.1	3.3
N2	12.3%	60.9	22.5	23.1	38.6	580.6	575.7	6.8
N3	5.8%	60.1	22.4	21.2	94.0	830.9	824.0	10.2
N4	3.6%	55.8	20.1	13.8	204.5	751.1	744.4	10.8
N5	3.6%	80.1	28.3	22.4	348.0	1046.7	1037.3	13.2
N6	1.5%	44.1	14.9	10.9	151.2	521.1	516.4	5.3
N7	0.2%	7.3	2.5	1.8	21.2	83.7	83.0	0.7
N8	0.8%	35.9	12.2	8.5	91.7	349.2	346.4	3.9
TOTAL	100.0%	375.6	146.0	207.7	1094.7	4639.0	4598.5	66.6
EPA switch duty cycle weighted brake-specific emissions			0.389	0.55	2.91	12.35	12.24	0.18
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

UP #9715 Test Date 10-29-98 CARB Diesel Fuel EM-2663-F Run #2/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	22	42.7	226	376	885	874	39
Low Idle	10	19.8	168	128	376	372	23
Idle	14	25.6	169	234	544	537	21
N1	195	81.0	142	165	1,704	1,687	30
N2	503	188.5	196	305	4,821	4,757	52
N3	1,037	389.4	438	2,121	13,933	13,791	203
N4	1,552	568.0	383	5,700	20,768	20,558	283
N5	2,222	792.8	627	9,876	28,173	27,888	380
N6	2,940	1,005.0	787	11,187	34,106	33,758	363
N7	3,664	1,235.4	970	10,206	41,973	41,543	334
N8	4,489	1,539.3	1,125	10,865	42,700	42,334	473
						sum =	

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.8	5.3	28.3	47.0	110.6	109.2	4.9
Low Idle	19.0%	1.9	3.8	31.9	24.3	71.4	70.6	4.4
Idle	19.0%	2.7	4.9	32.1	44.5	103.4	102.0	4.0
N1	6.5%	12.7	5.3	9.2	10.7	110.8	109.6	2.0
N2	6.5%	32.7	12.3	12.7	19.8	313.4	309.2	3.4
N3	5.2%	53.9	20.2	22.8	110.3	724.5	717.2	10.6
N4	4.4%	68.3	25.0	16.9	250.8	913.8	904.6	12.5
N5	3.8%	84.4	30.1	23.8	375.3	1070.6	1059.7	14.4
N6	3.9%	114.7	39.2	30.7	436.3	1330.1	1316.5	14.2
N7	3.0%	109.9	37.1	29.1	306.2	1259.2	1246.3	10.0
N8	16.2%	727.2	249.4	182.3	1760.1	6917.4	6858.1	76.6
TOTAL	100.0%	1211.1	432.5	419.7	3385.3	12925.2	12803.0	156.8
EPA line-haul duty cycle weighted brake-specific emissions			0.357	0.35	2.8	**10.7**	**10.6**	0.13
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	1.941	10.27	17.09	40.23	39.71	1.77
Low Idle	1.980	16.80	12.80	37.60	37.17	2.30
Idle	1.829	12.07	16.71	38.86	38.34	1.50
N1	0.415	0.73	0.85	8.74	8.65	0.15
N2	0.375	0.39	0.61	9.58	9.46	0.10
N3	0.376	0.42	2.05	13.44	13.30	0.20
N4	0.366	0.25	3.67	13.38	13.25	0.18
N5	0.357	0.28	4.44	12.68	12.55	0.17
N6	0.342	0.27	3.81	11.60	11.48	0.12
N7	0.337	0.26	2.79	11.46	11.34	0.09
N8	0.343	0.25	2.42	9.51	9.43	0.11

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	3.0	5.9	50.2	38.3	112.4	111.1	6.9
Idle	29.9%	4.2	7.7	50.5	70.0	162.7	160.5	6.3
N1	12.4%	24.2	10.0	17.6	20.5	211.3	209.2	3.7
N2	12.3%	61.9	23.2	24.1	37.5	593.0	585.1	6.4
N3	5.8%	60.1	22.6	25.4	123.0	808.1	799.9	11.8
N4	3.6%	55.9	20.4	13.8	205.2	747.6	740.1	10.2
N5	3.6%	80.0	28.5	22.6	355.5	1014.2	1004.0	13.7
N6	1.5%	44.1	15.1	11.8	167.8	511.6	506.4	5.4
N7	0.2%	7.3	2.5	1.9	20.4	83.9	83.1	0.7
N8	0.8%	35.9	12.3	9.0	86.9	341.6	338.7	3.8
TOTAL	100.0%	376.6	148.2	227.0	1125.1	4586.5	4538.0	68.8
EPA switch duty cycle weighted brake-specific emissions			0.394	0.60	2.99	12.18	12.05	0.18
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

UP #9715 Test Date 11-02-98 CARB Diesel Fuel EM-2663-F Run #3/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	31	42.8	197	336	899	891	32
Low Idle	10	20.3	159	163	380	377	22
Idle	10	22.0	137	179	485	482	18
N1	197	78.0	120	126	1,753	1,742	22
N2	502	185.0	179	275	4,770	4,739	48
N3	1,039	384.0	370	1,132	13,675	13,587	135
N4	1,554	562.0	370	5,055	20,299	20,168	214
N5	2,221	793.0	579	9,496	27,543	27,365	328
N6	2,941	1,008.0	735	11,647	32,921	32,708	365
N7	3,663	1,244.0	885	11,983	39,490	39,184	354
N8	4,492	1,548.0	1,037	12,577	41,934	41,690	467
							sum =

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	3.9	5.4	24.6	42.0	112.4	111.4	4.0
Low Idle	19.0%	1.9	3.9	30.2	31.0	72.2	71.7	4.2
Idle	19.0%	1.9	4.2	26.0	34.0	92.2	91.6	3.4
N1	6.5%	12.8	5.1	7.8	8.2	113.9	113.2	1.4
N2	6.5%	32.6	12.0	11.6	17.9	310.1	308.1	3.1
N3	5.2%	54.0	20.0	19.2	58.9	711.1	706.5	7.0
N4	4.4%	68.4	24.7	16.3	222.4	893.2	887.4	9.4
N5	3.8%	84.4	30.1	22.0	360.8	1046.6	1039.9	12.5
N6	3.9%	114.7	39.3	28.7	454.2	1283.9	1275.6	14.2
N7	3.0%	109.9	37.3	26.6	359.5	1184.7	1175.5	10.6
N8	16.2%	727.7	250.8	168.0	2037.5	6793.3	6753.8	75.7
TOTAL	100.0%	1212.2	432.7	381.0	3626.4	12613.5	12534.7	145.6
EPA line-haul duty cycle weighted brake-specific emissions			0.357	0.31	3.0	**10.4**	**10.3**	0.12
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	1.381	6.35	10.84	29.00	28.74	1.03
Low Idle	2.030	15.90	16.30	38.00	37.74	2.20
Idle	2.200	13.70	17.90	48.50	48.23	1.80
N1	0.396	0.61	0.64	8.90	8.84	0.11
N2	0.369	0.36	0.55	9.50	9.44	0.10
N3	0.370	0.36	1.09	13.16	13.08	0.13
N4	0.362	0.24	3.25	13.06	12.98	0.14
N5	0.357	0.26	4.28	12.40	12.32	0.15
N6	0.343	0.25	3.96	11.19	11.12	0.12
N7	0.340	0.24	3.27	10.78	10.70	0.10
N8	0.345	0.23	2.80	9.34	9.28	0.10

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	3.0	6.1	47.5	48.7	113.6	112.9	6.6
Idle	29.9%	3.0	6.6	41.0	53.5	145.0	144.2	5.4
N1	12.4%	24.4	9.7	14.9	15.6	217.4	216.0	2.7
N2	12.3%	61.7	22.8	22.0	33.8	586.7	583.0	5.9
N3	5.8%	60.3	22.3	21.5	65.7	793.2	788.0	7.8
N4	3.6%	55.9	20.2	13.3	182.0	730.8	726.0	7.7
N5	3.6%	80.0	28.5	20.8	341.9	991.5	985.2	11.8
N6	1.5%	44.1	15.1	11.0	174.7	493.8	490.6	5.5
N7	0.2%	7.3	2.5	1.8	24.0	79.0	78.4	0.7
N8	0.8%	35.9	12.4	8.3	100.6	335.5	333.5	3.7
TOTAL	100.0%	375.7	146.1	202.1	1040.5	4486.4	4457.7	57.9
EPA switch duty cycle weighted brake-specific emissions			0.389	0.54	2.77	11.94	11.87	0.15
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

APPENDIX E-3

UP No. 9715 Test Results Using On-Highway Diesel Fuel

UP #9715 Test Date 10-27-98 On-Highway Diesel Fuel EM-2677-F Run #1/3

SwRI Project 08-2062-001

Weighted Results

EPA Line-Haul

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)	Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	25	43.8	245	476	1009	995	32	DB-2	12.5%	3.1	5.5	30.6	59.5	126.1	124.4	4.0
Low Idle	11	20.0	187	260	429	422	24	Low Idle	19.0%	2.1	3.8	35.5	49.4	81.5	80.3	4.6
Idle	11	24.6	174	318	567	557	23	Idle	19.0%	2.1	4.7	33.1	60.4	107.7	105.9	4.4
N1	197	80.3	137	156	1,853	1,829	25	N1	6.5%	12.8	5.2	8.9	10.1	120.4	118.9	1.6
N2	497	186.0	201	289	5,216	5,145	49	N2	6.5%	32.3	12.1	13.1	18.8	339.0	334.4	3.2
N3	1,035	394.0	382	1,568	14,889	14,678	146	N3	5.2%	53.8	20.5	19.9	81.5	774.2	763.3	7.6
N4	1,551	574.3	441	5,279	22,634	22,296	249	N4	4.4%	68.2	25.3	19.4	232.3	995.9	981.0	11.0
N5	2,223	799.0	644	9,533	30,131	29,874	373	N5	3.8%	84.5	30.4	24.5	362.3	1145.0	1135.2	14.2
N6	2,941	1,020.0	796	11,160	36,031	35,709	408	N6	3.9%	114.7	39.8	31.0	435.2	1405.2	1392.7	15.9
N7	3,667	1,258.0	962	10,849	43,421	43,033	436	N7	3.0%	110.0	37.7	28.9	325.5	1302.6	1291.0	13.1
N8	4,495	1,553.0	1,132	11,954	44,933	44,427	558	N8	16.2%	728.2	251.6	183.4	1936.5	7279.1	7197.2	90.4
							sum =	TOTAL	100.0%	1211.9	436.5	428.2	3571.6	13676.9	13524.3	169.9
								EPA line-haul duty cycle weighted brake-specific emissions			0.360	0.35	2.9	**11.3**	**11.2**	0.14
								EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

EPA Switch Cycle

Individual Notch brake-specific emissions

Weighted Results

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)	Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	1.752	9.80	19.04	40.36	39.80	1.28	DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	1.818	17.00	23.64	39.00	38.41	2.18	Low Idle	29.9%	3.3	6.0	55.9	77.7	128.3	126.3	7.2
Idle	2.236	15.82	28.91	51.55	50.67	2.09	Idle	29.9%	3.3	7.4	52.0	95.1	169.5	166.7	6.9
N1	0.408	0.70	0.79	9.41	9.29	0.13	N1	12.4%	24.4	10.0	17.0	19.3	229.8	226.8	3.1
N2	0.374	0.40	0.58	10.49	10.35	0.10	N2	12.3%	61.1	22.9	24.7	35.5	641.6	632.8	6.0
N3	0.381	0.37	1.51	14.39	14.18	0.14	N3	5.8%	60.0	22.9	22.2	90.9	863.6	851.3	8.5
N4	0.370	0.28	3.40	14.59	14.38	0.16	N4	3.6%	55.8	20.7	15.9	190.0	814.8	802.7	9.0
N5	0.359	0.29	4.29	13.55	13.44	0.17	N5	3.6%	80.0	28.8	23.2	343.2	1084.7	1075.5	13.4
N6	0.347	0.27	3.79	12.25	12.14	0.14	N6	1.5%	44.1	15.3	11.9	167.4	540.5	535.6	6.1
N7	0.343	0.26	2.96	11.84	11.74	0.12	N7	0.2%	7.3	2.5	1.9	21.7	86.8	86.1	0.9
N8	0.345	0.25	2.66	10.00	9.88	0.12	N8	0.8%	36.0	12.4	9.1	95.6	359.5	355.4	4.5
							TOTAL	100.0%	375.4	148.7	233.8	1136.6	4919.0	4859.3	65.5
							EPA switch duty cycle weighted brake-specific emissions			0.396	0.62	3.03	13.10	12.94	0.17
							EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

UP #9715 Test Date 10-30-98 On-Highway Diesel Fuel EM-2677-F Run #2/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	25	40.8	215	446	891	879	27
Low Idle	11	16.0	150	194	299	295	19
Idle	11	27.0	190	348	579	569	23
N1	179	81.0	143	164	1,870	1,843	33
N2	507	183.8	208	320	5,023	4,955	53
N3	1,034	393.0	497	1,546	14,790	14,599	149
N4	1,549	574.5	401	5,397	21,707	21,480	243
N5	2,225	807.0	603	9,306	29,980	29,583	331
N6	2,942	1,021.5	753	11,656	35,316	34,910	355
N7	3,665	1,256.3	865	12,056	40,043	39,637	390
N8	4,478	1,554.0	1,096	11,772	42,708	42,186	522
							sum =

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	3.1	5.1	26.9	55.8	111.4	109.8	3.4
Low Idle	19.0%	2.1	3.0	28.5	36.9	56.8	56.0	3.6
Idle	19.0%	2.1	5.1	36.1	66.1	110.0	108.1	4.4
N1	6.5%	11.6	5.3	9.3	10.7	121.6	119.8	2.1
N2	6.5%	33.0	11.9	13.5	20.8	326.5	322.1	3.4
N3	5.2%	53.8	20.4	25.8	80.4	769.1	759.2	7.7
N4	4.4%	68.2	25.3	17.6	237.5	955.1	945.1	10.7
N5	3.8%	84.6	30.7	22.9	353.6	1139.2	1124.2	12.6
N6	3.9%	114.7	39.8	29.4	454.6	1377.3	1361.5	13.8
N7	3.0%	110.0	37.7	26.0	361.7	1201.3	1189.1	11.7
N8	16.2%	725.4	251.7	177.6	1907.1	6918.7	6834.1	84.6
TOTAL	100.0%	1208.5	436.1	413.6	3585.0	13087.0	12928.9	158.1
EPA line-haul duty cycle weighted brake-specific emissions			0.361	0.34	3.0	**10.8**	**10.7**	0.13
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	1.632	8.60	17.84	35.64	35.14	1.08
Low Idle	1.455	13.64	17.64	27.18	26.78	1.73
Idle	2.455	17.27	31.64	52.64	51.72	2.09
N1	0.453	0.80	0.92	10.45	10.30	0.18
N2	0.363	0.41	0.63	9.91	9.77	0.10
N3	0.380	0.48	1.50	14.30	14.12	0.14
N4	0.371	0.26	3.48	14.01	13.87	0.16
N5	0.363	0.27	4.18	13.47	13.30	0.15
N6	0.347	0.26	3.96	12.00	11.87	0.12
N7	0.343	0.24	3.29	10.93	10.82	0.11
N8	0.347	0.24	2.63	9.54	9.42	0.12

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	3.3	4.8	44.9	58.0	89.4	88.1	5.7
Idle	29.9%	3.3	8.1	56.8	104.1	173.1	170.1	6.9
N1	12.4%	22.2	10.0	17.7	20.3	231.9	228.6	4.1
N2	12.3%	62.4	22.6	25.6	39.4	617.8	609.5	6.5
N3	5.8%	60.0	22.8	28.8	89.7	857.8	846.8	8.6
N4	3.6%	55.8	20.7	14.4	194.3	781.5	773.3	8.7
N5	3.6%	80.1	29.1	21.7	335.0	1079.3	1065.0	11.9
N6	1.5%	44.1	15.3	11.3	174.8	529.7	523.7	5.3
N7	0.2%	7.3	2.5	1.7	24.1	80.1	79.3	0.8
N8	0.8%	35.8	12.4	8.8	94.2	341.7	337.5	4.2
TOTAL	100.0%	374.3	148.3	231.7	1133.9	4782.3	4721.7	62.8
EPA switch duty cycle weighted brake-specific emissions			0.396	0.62	3.03	12.78	12.62	0.17
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

UP #9715 Test Date 11-03-98 On-Highway Diesel Fuel EM-2677-F Run #3/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	22	41.1	212	417	900	896	33
Low Idle	10	17.4	165	208	304	304	23
Idle	10	21.8	148	246	490	490	20
N1	196	79.0	130	145	1,871	1,868	24
N2	499	185.0	187	294	5,104	5,084	52
N3	1,039	388.0	380	975	14,985	14,957	144
N4	1,550	563.0	405	4,904	21,765	21,709	206
N5	2,222	794.0	579	7,899	29,576	29,521	291
N6	2,939	1,009.0	742	10,227	34,702	34,636	332
N7	3,665	1,240.0	880	9,828	41,756	41,647	323
N8	4,495	1,518.0	972	11,863	41,741	41,575	463
							sum =

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.8	5.1	26.5	52.1	112.5	112.0	4.1
Low Idle	19.0%	1.9	3.3	31.4	39.5	57.8	57.8	4.4
Idle	19.0%	1.9	4.1	28.1	46.7	93.1	93.1	3.8
N1	6.5%	12.7	5.1	8.5	9.4	121.6	121.4	1.6
N2	6.5%	32.4	12.0	12.2	19.1	331.8	330.5	3.4
N3	5.2%	54.0	20.2	19.8	50.7	779.2	777.8	7.5
N4	4.4%	68.2	24.8	17.8	215.8	957.7	955.2	9.1
N5	3.8%	84.4	30.2	22.0	300.2	1123.9	1121.8	11.1
N6	3.9%	114.6	39.4	28.9	398.9	1353.4	1350.8	12.9
N7	3.0%	110.0	37.2	26.4	294.8	1252.7	1249.4	9.7
N8	16.2%	728.2	245.9	157.5	1921.8	6762.0	6735.1	75.0
TOTAL	100.0%	1211.2	427.3	379.0	3349.1	12945.6	12904.7	142.5

EPA line-haul duty cycle weighted brake-specific emissions	0.353	0.31	2.8	**10.7**	**10.7**	0.12
EPA line-haul duty cycle maximum Tier 0		1.00	5.0	9.5	9.5	0.60

EPA Switch Cycle

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	1.868	9.64	18.95	40.91	40.71	1.50
Low Idle	1.740	16.50	20.80	30.40	30.40	2.30
Idle	2.180	14.80	24.60	49.00	48.99	2.00
N1	0.403	0.66	0.74	9.55	9.53	0.12
N2	0.371	0.37	0.59	10.23	10.19	0.10
N3	0.373	0.37	0.94	14.42	14.40	0.14
N4	0.363	0.26	3.16	14.04	14.01	0.13
N5	0.357	0.26	3.55	13.31	13.29	0.13
N6	0.343	0.25	3.48	11.81	11.78	0.11
N7	0.338	0.24	2.68	11.39	11.36	0.09
N8	0.338	0.22	2.64	9.29	9.25	0.10

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	3.0	5.2	49.3	62.2	90.9	90.9	6.9
Idle	29.9%	3.0	6.5	44.3	73.6	146.5	146.5	6.0
N1	12.4%	24.3	9.8	16.1	18.0	232.0	231.6	3.0
N2	12.3%	61.4	22.8	23.0	36.2	627.8	625.4	6.4
N3	5.8%	60.3	22.5	22.0	56.6	869.1	867.5	8.4
N4	3.6%	55.8	20.3	14.6	176.5	783.5	781.5	7.4
N5	3.6%	80.0	28.6	20.8	284.4	1064.7	1062.8	10.5
N6	1.5%	44.1	15.1	11.1	153.4	520.5	519.5	5.0
N7	0.2%	7.3	2.5	1.8	19.7	83.5	83.3	0.6
N8	0.8%	36.0	12.1	7.8	94.9	333.9	332.6	3.7
TOTAL	100.0%	375.1	145.4	210.8	975.3	4752.6	4741.6	57.8

EPA switch duty cycle weighted brake-specific emissions	0.388	0.56	2.60	12.67	12.64	0.15
EPA switch cycle maximum Tier 0		2.10	8.0	14.0	14.0	0.72

APPENDIX E-4

UP No. 9715 Test Results Using High-Sulfur Diesel Fuel

UP #9715 Test Date 10-27-98 Nonroad High-Sulfur Diesel Fuel EM-2664-F Run #1/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	33	44.4	201	460	992	981	37
Low Idle	11	20.3	215	287	300	296	35
Idle	12	23.3	156	297	510	503	26
N1	195	79.2	134	166	2,020	1,993	31
N2	498	187.2	187	294	5,461	5,389	67
N3	1,042	393.6	372	1,491	15,536	15,354	202
N4	1,550	572.4	377	4,771	23,230	22,958	330
N5	2,224	799.2	623	9,713	31,554	31,218	465
N6	2,939	1,016.4	748	11,704	37,264	36,776	536
N7	3,662	1,251.6	888	11,810	45,212	44,654	665
N8	4,493	1,549.2	1,044	12,408	47,508	46,922	849
						sum =	

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	4.1	5.6	25.1	57.5	124.0	122.6	4.6
Low Idle	19.0%	2.1	3.9	40.9	54.5	57.0	56.2	6.7
Idle	19.0%	2.3	4.4	29.6	56.4	96.9	95.5	4.9
N1	6.5%	12.7	5.1	8.7	10.8	131.3	129.6	2.0
N2	6.5%	32.4	12.2	12.2	19.1	355.0	350.3	4.4
N3	5.2%	54.2	20.5	19.3	77.5	807.9	798.4	10.5
N4	4.4%	68.2	25.2	16.6	209.9	1022.1	1010.2	14.5
N5	3.8%	84.5	30.4	23.7	369.1	1199.1	1186.3	17.7
N6	3.9%	114.6	39.6	29.2	456.5	1453.3	1434.2	20.9
N7	3.0%	109.9	37.5	26.6	354.3	1356.4	1339.6	20.0
N8	16.2%	727.9	251.0	169.1	2010.1	7696.3	7601.4	137.5
TOTAL	100.0%	1212.8	435.3	401.0	3675.8	14299.2	14124.3	243.7
EPA line-haul duty cycle weighted brake-specific emissions			0.359	0.33	3.0	**11.8**	**11.6**	0.20
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	1.345	6.09	13.94	30.06	29.72	1.12
Low Idle	1.845	19.55	26.09	27.27	26.91	3.18
Idle	1.942	13.00	24.75	42.50	41.90	2.17
N1	0.406	0.69	0.85	10.36	10.22	0.16
N2	0.376	0.38	0.59	10.97	10.82	0.13
N3	0.378	0.36	1.43	14.91	14.74	0.19
N4	0.369	0.24	3.08	14.99	14.81	0.21
N5	0.359	0.28	4.37	14.19	14.04	0.21
N6	0.346	0.25	3.98	12.68	12.51	0.18
N7	0.342	0.24	3.23	12.35	12.19	0.18
N8	0.345	0.23	2.76	10.57	10.44	0.19

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	3.3	6.1	64.3	85.8	89.7	88.5	10.5
Idle	29.9%	3.6	7.0	46.6	88.8	152.5	150.3	7.8
N1	12.4%	24.2	9.8	16.6	20.6	250.5	247.2	3.8
N2	12.3%	61.3	23.0	23.0	36.2	671.7	662.8	8.2
N3	5.8%	60.4	22.8	21.6	86.5	901.1	890.6	11.7
N4	3.6%	55.8	20.6	13.6	171.8	836.3	826.5	11.9
N5	3.6%	80.1	28.8	22.4	349.7	1135.9	1123.8	16.7
N6	1.5%	44.1	15.2	11.2	175.6	559.0	551.6	8.0
N7	0.2%	7.3	2.5	1.8	23.6	90.4	89.3	1.3
N8	0.8%	35.9	12.4	8.4	99.3	380.1	375.4	6.8
TOTAL	100.0%	376.0	148.2	229.5	1137.7	5067.1	5006.1	86.8
EPA switch duty cycle weighted brake-specific emissions			0.394	0.61	3.03	13.48	13.32	0.23
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

UP #9715 Test Date 10-28-98 Nonroad High-Sulfur Diesel Fuel EM-2664-F Run #2/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	23	40.3	198	528	814	801	42
Low Idle	10	21.3	204	315	292	287	41
Idle	11	22.8	152	359	469	462	29
N1	194	83.5	134	189	2,112	2,085	50
N2	495	186.0	160	299	5,333	5,269	105
N3	1,021	394.3	337	1,577	15,142	14,957	289
N4	1,538	571.5	368	5,230	22,363	22,106	399
N5	2,224	800.4	544	9,512	32,173	31,725	537
N6	2,940	1,019.5	687	12,320	37,713	37,187	638
N7	3,666	1,252.8	802	11,948	43,658	43,078	744
N8	4,484	1,557.0	976	14,018	45,730	45,041	1,014
						sum =	

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.9	5.0	24.8	66.0	101.8	100.2	5.3
Low Idle	19.0%	1.9	4.0	38.8	59.9	55.5	54.5	7.8
Idle	19.0%	2.1	4.3	28.9	68.2	89.1	87.8	5.5
N1	6.5%	12.6	5.4	8.7	12.3	137.3	135.5	3.3
N2	6.5%	32.2	12.1	10.4	19.4	346.6	342.5	6.8
N3	5.2%	53.1	20.5	17.5	82.0	787.4	777.8	15.0
N4	4.4%	67.7	25.1	16.2	230.1	984.0	972.7	17.6
N5	3.8%	84.5	30.4	20.7	361.5	1222.6	1205.6	20.4
N6	3.9%	114.7	39.8	26.8	480.5	1470.8	1450.3	24.9
N7	3.0%	110.0	37.6	24.1	358.4	1309.7	1292.4	22.3
N8	16.2%	726.4	252.2	158.1	2270.9	7408.3	7296.7	164.3
TOTAL	100.0%	1208.0	436.6	374.9	4009.2	13913.0	13715.8	293.1
EPA line-haul duty cycle weighted brake-specific emissions			0.361	0.31	3.3	**11.5**	**11.4**	0.24
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	1.752	8.61	22.96	35.39	34.84	1.83
Low Idle	2.130	20.40	31.50	29.20	28.70	4.10
Idle	2.073	13.82	32.64	42.64	42.00	2.64
N1	0.430	0.69	0.97	10.89	10.74	0.26
N2	0.376	0.32	0.60	10.77	10.64	0.21
N3	0.386	0.33	1.54	14.83	14.65	0.28
N4	0.372	0.24	3.40	14.54	14.37	0.26
N5	0.360	0.24	4.28	14.47	14.27	0.24
N6	0.347	0.23	4.19	12.83	12.65	0.22
N7	0.342	0.22	3.26	11.91	11.75	0.20
N8	0.347	0.22	3.13	10.20	10.04	0.23

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	3.0	6.4	61.0	94.2	87.3	85.8	12.3
Idle	29.9%	3.3	6.8	45.4	107.3	140.2	138.1	8.7
N1	12.4%	24.1	10.4	16.6	23.4	261.9	258.5	6.2
N2	12.3%	60.9	22.9	19.7	36.8	656.0	648.1	12.9
N3	5.8%	59.2	22.9	19.5	91.5	878.2	867.5	16.8
N4	3.6%	55.4	20.6	13.2	188.3	805.1	795.8	14.4
N5	3.6%	80.1	28.8	19.6	342.4	1158.2	1142.1	19.3
N6	1.5%	44.1	15.3	10.3	184.8	565.7	557.8	9.6
N7	0.2%	7.3	2.5	1.6	23.9	87.3	86.2	1.5
N8	0.8%	35.9	12.5	7.8	112.1	365.8	360.3	8.1
TOTAL	100.0%	373.2	148.9	214.8	1204.8	5005.8	4940.3	109.7
EPA switch duty cycle weighted brake-specific emissions			0.399	0.58	3.23	13.41	13.24	0.29
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

UP #9715 Test Date 11-03-98 Nonroad High-Sulfur Diesel Fuel EM-2664-F Run #3/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	23	37.5	164	399	818	816	30
Low Idle	10	24.0	238	330	343	342	39
Idle	10	29.3	171	362	646	643	34
N1	197	82.0	122	150	2,066	2,059	31
N2	501	185.0	177	263	5,274	5,254	77
N3	1,033	387.0	368	941	14,752	14,686	203
N4	1,548	569.0	398	3,344	22,695	22,622	317
N5	2,223	799.0	590	7,737	30,515	30,457	298
N6	2,939	1,012.0	718	10,482	35,525	35,457	539
N7	3,665	1,243.0	883	10,286	42,498	42,362	621
N8	4,445	1,544.0	1,028	10,841	45,523	45,435	841
						sum =	

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.9	4.7	20.5	49.9	102.3	102.0	3.8
Low Idle	19.0%	1.9	4.6	45.2	62.7	65.2	65.0	7.4
Idle	19.0%	1.9	5.6	32.5	68.8	122.7	122.2	6.5
N1	6.5%	12.8	5.3	7.9	9.8	134.3	133.9	2.0
N2	6.5%	32.6	12.0	11.5	17.1	342.8	341.5	5.0
N3	5.2%	53.7	20.1	19.1	48.9	767.1	763.7	10.6
N4	4.4%	68.1	25.0	17.5	147.1	998.6	995.4	13.9
N5	3.8%	84.5	30.4	22.4	294.0	1159.6	1157.4	11.3
N6	3.9%	114.6	39.5	28.0	408.8	1385.5	1382.8	21.0
N7	3.0%	110.0	37.3	26.5	308.6	1274.9	1270.8	18.6
N8	16.2%	720.1	250.1	166.5	1756.2	7374.7	7360.4	136.2
TOTAL	100.0%	1203.0	434.6	397.7	3171.9	13727.7	13695.0	236.4
EPA line-haul duty cycle weighted brake-specific emissions			0.361	0.33	2.6	**11.4**	**11.4**	0.20
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	1.630	7.13	17.35	35.57	35.46	1.30
Low Idle	2.400	23.80	33.00	34.30	34.19	3.90
Idle	2.930	17.10	36.20	64.60	64.31	3.40
N1	0.416	0.62	0.76	10.49	10.45	0.16
N2	0.369	0.35	0.52	10.53	10.49	0.15
N3	0.375	0.36	0.91	14.28	14.22	0.20
N4	0.368	0.26	2.16	14.66	14.61	0.20
N5	0.359	0.27	3.48	13.73	13.70	0.13
N6	0.344	0.24	3.57	12.09	12.06	0.18
N7	0.339	0.24	2.81	11.60	11.56	0.17
N8	0.347	0.23	2.44	10.24	10.22	0.19

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	3.0	7.2	71.2	98.7	102.6	102.2	11.7
Idle	29.9%	3.0	8.8	51.1	108.2	193.2	192.3	10.2
N1	12.4%	24.4	10.2	15.1	18.6	256.2	255.4	3.8
N2	12.3%	61.6	22.8	21.8	32.3	648.7	646.2	9.5
N3	5.8%	59.9	22.4	21.3	54.6	855.6	851.8	11.8
N4	3.6%	55.7	20.5	14.3	120.4	817.0	814.4	11.4
N5	3.6%	80.0	28.8	21.2	278.5	1098.5	1096.4	10.7
N6	1.5%	44.1	15.2	10.8	157.2	532.9	531.9	8.1
N7	0.2%	7.3	2.5	1.8	20.6	85.0	84.7	1.2
N8	0.8%	35.6	12.4	8.2	86.7	364.2	363.5	6.7
TOTAL	100.0%	374.7	150.6	236.9	975.9	4953.8	4938.8	85.1
EPA switch duty cycle weighted brake-specific emissions			0.402	0.63	2.60	13.22	13.18	0.23
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

APPENDIX E-5

UP No. 9715 Test Results Using 0.3% Sulfur Diesel Fuel

UP #9715 Test Date 10-30-98 0.3% Sulfur Diesel Fuel EM-2708-F Run #1/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	33	42.6	218	446	935	925	35
Low Idle	11	21.6	228	264	358	355	32
Idle	11	25.8	183	313	560	554	24
N1	197	79.0	138	155	1,967	1,948	24
N2	502	187.0	183	276	4,720	4,672	51
N3	1,023	390.0	370	1,425	14,905	14,779	155
N4	1,551	569.0	385	4,829	21,868	21,629	237
N5	2,224	802.0	580	9,404	35,074	35,183	355
N6	2,942	1,021.0	743	12,925	36,141	35,850	426
N7	3,744	1,254.0	882	11,993	41,992	41,624	486
N8	4,493	1,548.0	1,009	12,170	45,683	47,213	628
							sum =

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	4.1	5.3	27.3	55.8	116.9	115.6	4.4
Low Idle	19.0%	2.1	4.1	43.3	50.2	68.0	67.4	6.1
Idle	19.0%	2.1	4.9	34.8	59.5	106.4	105.3	4.6
N1	6.5%	12.8	5.1	9.0	10.1	127.9	126.6	1.6
N2	6.5%	32.6	12.2	11.9	17.9	306.8	303.6	3.3
N3	5.2%	53.2	20.3	19.2	74.1	775.1	768.5	8.1
N4	4.4%	68.2	25.0	16.9	212.5	962.2	951.7	10.4
N5	3.8%	84.5	30.5	22.0	357.4	1332.8	1337.0	13.5
N6	3.9%	114.7	39.8	29.0	504.1	1409.5	1398.2	16.6
N7	3.0%	112.3	37.6	26.5	359.8	1259.8	1248.7	14.6
N8	16.2%	727.9	250.8	163.5	1971.5	7400.6	7648.6	101.7
TOTAL	100.0%	1214.6	435.6	403.3	3672.7	13865.9	14071.2	184.8
EPA line-haul duty cycle weighted brake-specific emissions			0.359	0.33	3.0	**11.4**	**11.6**	0.15
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	1.291	6.61	13.52	28.33	28.02	1.06
Low Idle	1.964	20.73	24.00	32.55	32.24	2.91
Idle	2.345	16.64	28.45	50.91	50.40	2.18
N1	0.401	0.70	0.79	9.98	9.89	0.12
N2	0.373	0.36	0.55	9.40	9.31	0.10
N3	0.381	0.36	1.39	14.57	14.45	0.15
N4	0.367	0.25	3.11	14.10	13.95	0.15
N5	0.361	0.26	4.23	15.77	15.82	0.16
N6	0.347	0.25	4.39	12.28	12.19	0.14
N7	0.335	0.24	3.20	11.22	11.12	0.13
N8	0.345	0.22	2.71	10.17	10.51	0.14

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	3.3	6.5	68.2	78.9	107.0	106.1	9.6
Idle	29.9%	3.3	7.7	54.7	93.6	167.4	165.8	7.2
N1	12.4%	24.4	9.8	17.1	19.2	243.9	241.6	3.0
N2	12.3%	61.7	23.0	22.5	33.9	580.6	574.6	6.3
N3	5.8%	59.3	22.6	21.5	82.7	864.5	857.2	9.0
N4	3.6%	55.8	20.5	13.9	173.8	787.2	778.6	8.5
N5	3.6%	80.1	28.9	20.9	338.5	1262.7	1266.6	12.8
N6	1.5%	44.1	15.3	11.1	193.9	542.1	537.8	6.4
N7	0.2%	7.5	2.5	1.8	24.0	84.0	83.2	1.0
N8	0.8%	35.9	12.4	8.1	97.4	365.5	377.7	5.0
TOTAL	100.0%	375.5	149.2	239.7	1136.0	5004.9	4989.1	68.7
EPA switch duty cycle weighted brake-specific emissions			0.397	0.64	3.02	13.33	13.28	0.18
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

UP #9715 Test Date 11-02-98 0.3% Sulfur Diesel Fuel EM-2708-F Run #2/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	24	40.7	194	405	888	877	42
Low Idle	10	18.6	198	277	272	268	30
Idle	10	28.8	204	388	630	621	31
N1	197	84.0	172	215	2,564	2,533	32
N2	500	189.0	221	346	6,592	6,513	69
N3	1,041	397.0	393	1,467	15,375	15,208	205
N4	1,548	573.0	362	4,961	22,250	22,031	273
N5	2,220	802.0	565	9,609	30,779	30,422	410
N6	2,939	1,021.0	707	13,292	35,613	35,240	500
N7	3,667	1,249.0	909	11,883	43,597	43,091	511
N8	4,451	1,553.0	1,014	14,396	45,016	44,561	803
						sum =	

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	3.0	5.1	24.3	50.6	111.0	109.6	5.3
Low Idle	19.0%	1.9	3.5	37.6	52.6	51.7	51.0	5.7
Idle	19.0%	1.9	5.5	38.8	73.7	119.7	118.0	5.9
N1	6.5%	12.8	5.5	11.2	14.0	166.7	164.6	2.1
N2	6.5%	32.5	12.3	14.4	22.5	428.5	423.4	4.5
N3	5.2%	54.1	20.6	20.4	76.3	799.5	790.8	10.7
N4	4.4%	68.1	25.2	15.9	218.3	979.0	969.4	12.0
N5	3.8%	84.4	30.5	21.5	365.1	1169.6	1156.0	15.6
N6	3.9%	114.6	39.8	27.6	518.4	1388.9	1374.4	19.5
N7	3.0%	110.0	37.5	27.3	356.5	1307.9	1292.7	15.3
N8	16.2%	721.1	251.6	164.3	2332.2	7292.6	7218.9	130.1
TOTAL	100.0%	1204.4	437.0	403.1	4080.2	13815.0	13668.9	226.6
EPA line-haul duty cycle weighted brake-specific emissions			0.363	0.33	3.4	**11.5**	**11.3**	0.19
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	1.696	8.08	16.88	37.00	36.55	1.75
Low Idle	1.860	19.80	27.70	27.20	26.84	3.00
Idle	2.880	20.40	38.80	63.00	62.11	3.10
N1	0.426	0.87	1.09	13.02	12.86	0.16
N2	0.378	0.44	0.69	13.18	13.03	0.14
N3	0.381	0.38	1.41	14.77	14.61	0.20
N4	0.370	0.23	3.20	14.37	14.23	0.18
N5	0.361	0.25	4.33	13.86	13.70	0.18
N6	0.347	0.24	4.52	12.12	11.99	0.17
N7	0.341	0.25	3.24	11.89	11.75	0.14
N8	0.349	0.23	3.23	10.11	10.01	0.18

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	3.0	5.6	59.2	82.8	81.3	80.2	9.0
Idle	29.9%	3.0	8.6	61.0	116.0	188.4	185.7	9.3
N1	12.4%	24.4	10.4	21.3	26.7	317.9	314.0	4.0
N2	12.3%	61.5	23.2	27.2	42.6	810.8	801.2	8.5
N3	5.8%	60.4	23.0	22.8	85.1	891.8	882.1	11.9
N4	3.6%	55.7	20.6	13.0	178.6	801.0	793.1	9.8
N5	3.6%	79.9	28.9	20.3	345.9	1108.0	1095.2	14.8
N6	1.5%	44.1	15.3	10.6	199.4	534.2	528.6	7.5
N7	0.2%	7.3	2.5	1.8	23.8	87.2	86.2	1.0
N8	0.8%	35.6	12.4	8.1	115.2	360.1	356.5	6.4
TOTAL	100.0%	375.0	150.6	245.4	1216.0	5180.8	5122.8	82.1
EPA switch duty cycle weighted brake-specific emissions			0.402	0.65	3.24	13.82	13.66	0.22
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

UP #9715 Test Date 11-04-98 0.3% Sulfur Diesel Fuel EM-2708-F Run #3/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	23	46.0	169	410	831	825	44
Low Idle	10	19.8	196	271	278	275	34
Idle	10	23.3	136	288	510	506	27
N1	195	81.0	120	148	1,998	1,982	33
N2	500	188.0	180	267	5,296	5,262	68
N3	1,041	389.0	370	944	14,633	14,523	189
N4	1,550	567.0	396	3,325	22,159	21,976	252
N5	2,221	794.0	586	7,672	29,686	29,473	300
N6	2,942	1,009.0	716	10,428	34,763	34,539	382
N7	3,664	1,234.0	878	10,190	41,444	41,133	514
N8	4,469	1,527.0	1,018	10,698	44,013	43,682	748
							sum =

Weighted Results

Notch	EPA Line-Haul WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.9	5.8	21.1	51.3	103.9	103.1	5.5
Low Idle	19.0%	1.9	3.8	37.2	51.5	52.8	52.3	6.5
Idle	19.0%	1.9	4.4	25.8	54.7	96.9	96.2	5.1
N1	6.5%	12.7	5.3	7.8	9.6	129.9	128.8	2.1
N2	6.5%	32.5	12.2	11.7	17.4	344.2	342.0	4.4
N3	5.2%	54.1	20.2	19.2	49.1	760.9	755.2	9.8
N4	4.4%	68.2	24.9	17.4	146.3	975.0	966.9	11.1
N5	3.8%	84.4	30.2	22.3	291.5	1128.1	1120.0	11.4
N6	3.9%	114.7	39.4	27.9	406.7	1355.8	1347.0	14.9
N7	3.0%	109.9	37.0	26.3	305.7	1243.3	1234.0	15.4
N8	16.2%	724.0	247.4	164.9	1733.1	7130.1	7076.6	121.2
TOTAL	100.0%	1207.2	430.5	381.8	3116.8	13320.9	13222.2	207.5
EPA line-haul duty cycle weighted brake-specific emissions			0.357	0.32	2.6	**11.0**	**11.0**	0.17
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	2.000	7.35	17.83	36.13	35.86	1.91
Low Idle	1.980	19.60	27.10	27.80	27.54	3.40
Idle	2.330	13.60	28.80	51.00	50.64	2.70
N1	0.415	0.62	0.76	10.25	10.16	0.17
N2	0.376	0.36	0.53	10.59	10.52	0.14
N3	0.374	0.36	0.91	14.06	13.95	0.18
N4	0.366	0.26	2.15	14.30	14.18	0.16
N5	0.357	0.26	3.45	13.37	13.27	0.14
N6	0.343	0.24	3.54	11.82	11.74	0.13
N7	0.337	0.24	2.78	11.31	11.23	0.14
N8	0.342	0.23	2.39	9.85	9.77	0.17

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	3.0	5.9	58.6	81.0	83.1	82.4	10.2
Idle	29.9%	3.0	7.0	40.7	86.1	152.5	151.4	8.1
N1	12.4%	24.2	10.0	14.9	18.4	247.8	245.7	4.1
N2	12.3%	61.5	23.1	22.1	32.8	651.4	647.2	8.4
N3	5.8%	60.4	22.6	21.5	54.8	848.7	842.3	11.0
N4	3.6%	55.8	20.4	14.3	119.7	797.7	791.1	9.1
N5	3.6%	80.0	28.6	21.1	276.2	1068.7	1061.0	10.8
N6	1.5%	44.1	15.1	10.7	156.4	521.4	518.1	5.7
N7	0.2%	7.3	2.5	1.8	20.4	82.9	82.3	1.0
N8	0.8%	35.8	12.2	8.1	85.6	352.1	349.5	6.0
TOTAL	100.0%	375.0	147.4	213.7	931.4	4806.3	4771.0	74.3
EPA switch duty cycle weighted brake-specific emissions			0.393	0.57	2.48	12.82	12.72	0.20
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

APPENDIX E-6

UP No. 9715 Smoke Test Summary

SMOKE TEST SUMMARY FOR UP NO. 9715

Run #	**ss**	**30-sec**	**3-sec**
Carb Diesel (EM-2663-F)			
# 1	16	17	71
# 2	11	17	65
# 3	15	20	69
Avg	**14**	**18**	**68**
cov	19%	10%	4%
On-Highway Diesel (EM-2677-F)			
# 1	8	13	60
# 2	9	14	64
# 3	11	15	69
Avg	**9**	**14**	**64**
cov	16%	7%	7%
Nonroad High Sulfur Diesel (EM-2664-F)			
# 1	5	6	38
# 2	19	14	61
# 3	9	13	57
Avg	**11**	**11**	**52**
cov	66%	40%	24%
Fuel #4, Nonroad 0.3% Sulfur Diesel (EM-2708-F)			
# 1	8	13	61
# 2	13	14	53
# 3	9	12	49
Avg	**10**	**13**	**54**
cov	26%	8%	11%

updated 11/18/98 sgf

APPENDIX F-1

UP No. 9733 Test Summary

EPA Line-Haul Duty Cycle Weighting Factors

	obs bsfc	HC	CO	EPA NOx	KH-NOx	PM	
	lb/hp-hr	g/hp-hr	g/hp-hr	g/hp-hr	g/hp-hr	g/hp-hr	
Carb Diesel (EM-2663-F)							
	0.357	0.32	3.5	10.922	10.703	0.14	
	0.357	0.33	3.0	11.026	10.942	0.11	
	0.356	0.30	3.5	10.931	10.833	0.12	
Avg	**0.357**	**0.316**	**3.30**	**10.960**	**10.826**	**0.126**	
cov	0.2%	5.1%	8.4%	0.5%	1.1%	13.0%	
On-Highway Diesel (EM-2677-F)							
	0.359	0.32	3.4	11.111	11.030	0.13	
	0.359	0.33	3.1	11.245	11.148	0.13	
	0.363	0.31	3.9	11.290	11.134	0.14	
Avg	**0.361**	**0.321**	**3.46**	**11.215**	**11.104**	**0.132**	
cov	0.7%	3.9%	10.9%	0.8%	0.6%	4.5%	
Nonroad High Sulfur Diesel (EM-2664-F)							
	0.360	0.30	3.5	11.572	11.485	0.21	
	0.361	0.29	3.5	11.726	11.570	0.20	
	0.361	0.31	3.6	11.665	11.571	0.20	
Avg	**0.361**	**0.300**	**3.54**	**11.654**	**11.542**	**0.203**	
cov	0.1%	2.3%	1.3%	0.7%	0.4%	2.3%	
0.3% Sulfur Diesel (EM-2708-F)							
	0.361	0.30	3.5	11.461	11.390	0.16	
	0.362	0.31	3.4	11.610	11.480	0.17	
	0.362	0.30	3.6	11.510	11.356	0.18	
Avg	**0.361**	**0.304**	**3.49**	**11.527**	**11.409**	**0.171**	
cov	0.2%	0.8%	2.2%	0.7%	0.6%	4.4%	
	-1.1%	5%	-7%	-6%	-6%	-38%	carb vs HS
	-0.1%	7%	-2%	-4%	-4%	-35%	on-hwy vs HS
	-1.0%	-2%	-5%	-2%	-3%	-4%	carb vs on-hwy

Note: EPA NOx = full NOx correction factor
Note: KH NOx = only ambient air humidity NOx correction factor applied

-1.3%	4.0%	-5.3%	-4.9%	-5.1%	-26.3%	carb vs 0.3% S
-0.2%	5.6%	-0.7%	-2.7%	-2.7%	-23.2%	on-hwy vs 0.3% S

UP 9733
GE DASH9-44CW
updated 06-29-99

EPA Switcher Duty Cycle Weighting Factors

	obs bsfc	HC	CO	EPA NOx	KH-NOx	PM	
	lb/hp-hr	g/hp-hr	g/hp-hr	g/hp-hr	g/hp-hr	g/hp-hr	
Carb Diesel (EM-2663-F)							
	0.397	0.55	3.23	12.978	12.725	0.17	
	0.397	0.55	2.88	13.099	13.002	0.15	
	0.387	0.47	3.16	12.735	12.608	0.14	
Avg	**0.394**	**0.525**	**3.09**	**12.937**	**12.778**	**0.155**	
cov	1.5%	8.3%	6.0%	1.4%	1.6%	10.1%	
On-Highway Diesel (EM-2677-F)							
	0.397	0.55	3.13	13.402	13.294	0.15	
	0.399	0.62	2.92	13.512	13.397	0.17	
	0.401	0.55	3.55	13.570	13.378	0.17	
Avg	**0.399**	**0.574**	**3.20**	**13.495**	**13.356**	**0.164**	
cov	0.5%	6.6%	10.0%	0.6%	0.4%	7.5%	
Nonroad High Sulfur Diesel (EM-2664-F)							
	0.398	0.54	3.19	13.921	13.820	0.26	
	0.399	0.53	3.03	14.080	13.882	0.26	
	0.398	0.53	3.27	13.777	13.656	0.23	
Avg	**0.398**	**0.535**	**3.16**	**13.926**	**13.786**	**0.247**	
cov	0.2%	1.4%	3.8%	1.1%	0.8%	6.4%	
0.3% Sulfur Diesel (EM-2708-F)							
	0.399	0.60	3.10	13.886	13.794	0.20	
	0.399	0.57	2.95	13.992	13.816	0.21	
	0.400	0.54	3.32	13.787	13.597	0.21	
Avg	**0.400**	**0.573**	**3.12**	**13.889**	**13.736**	**0.206**	
cov	0.2%	5.3%	6.0%	0.7%	0.9%	4.4%	
	-1.2%	-2%	-2%	-7%	-7%	-37%	carb vs HS
	0.2%	7%	1%	-3%	-3%	-34%	on-hwy vs HS
	-1.4%	-9%	-3%	-4%	-4%	-5%	carb vs on-hwy

APPENDIX F-2

UP No. 9733 Test Results Using CARB Diesel Fuel

UP #9733 Test Date 5-17-99 CARB Diesel Fuel EM-2663-F Run #1/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	23	47.3	207	312	1,054	1,033	30
Low Idle	11	20.1	180	167	370	363	17
Idle	10	24.0	130	167	592	580	17
N1	195	79.0	105	108	1,831	1,795	38
N2	496	192.0	174	374	5,245	5,148	79
N3	1,037	396.0	370	2,151	15,580	15,275	137
N4	1,553	575.0	383	7,138	21,952	21,534	246
N5	2,221	796.0	577	10,008	29,228	28,657	344
N6	2,940	1,012.0	746	10,915	35,554	34,830	348
N7	3,660	1,244.0	851	12,396	41,723	40,887	365
N8	4,490	1,527.0	1,073	15,216	42,713	41,843	623
							sum =

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.9	5.9	25.9	39.0	131.8	129.1	3.8
Low Idle	19.0%	2.1	3.8	34.2	31.7	70.3	69.0	3.2
Idle	19.0%	1.9	4.6	24.7	31.7	112.5	110.2	3.2
N1	6.5%	12.7	5.1	6.8	7.0	119.0	116.7	2.5
N2	6.5%	32.2	12.5	11.3	24.3	340.9	334.6	5.1
N3	5.2%	53.9	20.6	19.2	111.9	810.2	794.3	7.1
N4	4.4%	68.3	25.3	16.9	314.1	965.9	947.5	10.8
N5	3.8%	84.4	30.2	21.9	380.3	1110.7	1089.0	13.1
N6	3.9%	114.7	39.5	29.1	425.7	1386.6	1358.4	13.6
N7	3.0%	109.8	37.3	25.5	371.9	1251.7	1226.6	11.0
N8	16.2%	727.4	247.4	173.8	2465.0	6919.5	6778.5	100.9
TOTAL	100.0%	1210.3	432.2	389.4	4202.6	13219.0	12953.8	174.3
EPA line-haul duty cycle weighted brake-specific emissions			0.357	0.32	3.5	**10.9**	**10.7**	0.14
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	2.057	9.00	13.57	45.83	44.89	1.30
Low Idle	1.827	16.36	15.18	33.64	33.02	1.55
Idle	2.400	13.00	16.70	59.20	57.98	1.70
N1	0.405	0.54	0.55	9.39	9.20	0.19
N2	0.387	0.35	0.75	10.57	10.38	0.16
N3	0.382	0.36	2.07	15.02	14.73	0.13
N4	0.370	0.25	4.60	14.14	13.87	0.16
N5	0.358	0.26	4.51	13.16	12.90	0.15
N6	0.344	0.25	3.71	12.09	11.85	0.12
N7	0.340	0.23	3.39	11.40	11.17	0.10
N8	0.340	0.24	3.39	9.51	9.32	0.14

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	3.3	6.0	53.8	49.9	110.6	108.6	5.1
Idle	29.9%	3.0	7.2	38.9	49.9	177.0	173.4	5.1
N1	12.4%	24.2	9.8	13.0	13.4	227.0	222.6	4.7
N2	12.3%	61.0	23.6	21.4	46.0	645.1	633.2	9.7
N3	5.8%	60.1	23.0	21.5	124.8	903.6	885.9	7.9
N4	3.6%	55.9	20.7	13.8	257.0	790.3	775.2	8.9
N5	3.6%	80.0	28.7	20.8	360.3	1052.2	1031.7	12.4
N6	1.5%	44.1	15.2	11.2	163.7	533.3	522.4	5.2
N7	0.2%	7.3	2.5	1.7	24.8	83.4	81.8	0.7
N8	0.8%	35.9	12.2	8.6	121.7	341.7	334.7	5.0
TOTAL	100.0%	374.8	148.8	204.6	1211.5	4864.4	4769.5	64.7
EPA switch duty cycle weighted brake-specific emissions			0.397	0.55	3.23	12.98	12.72	0.17
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

UP #9733 Test Date 5-18-99 CARB Diesel Fuel EM-2663-F Run #2/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	23	41.4	190	288	1002	991	35
Low Idle	10	19.4	169	165	372	368	17
Idle	10	24.6	134	178	609	603	17
N1	190	79.0	119	106	1,820	1,804	37
N2	498	191.0	187	334	5,320	5,282	68
N3	1,038	398.0	360	1,887	15,424	15,315	128
N4	1,549	574.0	373	6,632	22,192	22,030	215
N5	2,220	791.0	637	8,666	29,536	29,326	273
N6	2,939	1,004.0	723	9,126	35,910	35,664	240
N7	3,665	1,236.0	880	10,112	43,118	42,811	273
N8	4,491	1,538.0	1,125	12,950	43,031	42,689	453
						sum =	

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.9	5.2	23.8	36.0	125.3	123.9	4.4
Low Idle	19.0%	1.9	3.7	32.1	31.4	70.7	69.9	3.2
Idle	19.0%	1.9	4.7	25.5	33.8	115.7	114.6	3.2
N1	6.5%	12.4	5.1	7.7	6.9	118.3	117.3	2.4
N2	6.5%	32.4	12.4	12.2	21.7	345.8	343.3	4.4
N3	5.2%	54.0	20.7	18.7	98.1	802.0	796.4	6.7
N4	4.4%	68.2	25.3	16.4	291.8	976.4	969.3	9.5
N5	3.8%	84.4	30.1	24.2	329.3	1122.4	1114.4	10.4
N6	3.9%	114.6	39.2	28.2	355.9	1400.5	1390.9	9.4
N7	3.0%	110.0	37.1	26.4	303.4	1293.5	1284.3	8.2
N8	16.2%	727.5	249.2	182.3	2097.9	6971.0	6915.6	73.4
TOTAL	100.0%	1210.0	432.5	397.4	3606.2	13341.7	13240.0	135.1
EPA line-haul duty cycle weighted brake-specific emissions			0.357	0.33	3.0	**11.0**	**10.9**	0.11
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	1.800	8.26	12.52	43.57	43.10	1.52
Low Idle	1.940	16.90	16.50	37.20	36.79	1.70
Idle	2.460	13.40	17.80	60.90	60.33	1.70
N1	0.416	0.63	0.56	9.58	9.50	0.19
N2	0.384	0.38	0.67	10.68	10.61	0.14
N3	0.383	0.35	1.82	14.86	14.75	0.12
N4	0.371	0.24	4.28	14.33	14.22	0.14
N5	0.356	0.29	3.90	13.30	13.21	0.12
N6	0.342	0.25	3.11	12.22	12.13	0.08
N7	0.337	0.24	2.76	11.76	11.68	0.07
N8	0.342	0.25	2.88	9.58	9.51	0.10

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	3.0	5.8	50.5	49.3	111.2	110.0	5.1
Idle	29.9%	3.0	7.4	40.1	53.2	182.1	180.4	5.1
N1	12.4%	23.6	9.8	14.8	13.1	225.7	223.7	4.6
N2	12.3%	61.3	23.5	23.0	41.1	654.4	649.7	8.4
N3	5.8%	60.2	23.1	20.9	109.4	894.6	888.3	7.4
N4	3.6%	55.8	20.7	13.4	238.8	798.9	793.1	7.7
N5	3.6%	79.9	28.5	22.9	312.0	1063.3	1055.7	9.8
N6	1.5%	44.1	15.1	10.8	136.9	538.7	535.0	3.6
N7	0.2%	7.3	2.5	1.8	20.2	86.2	85.6	0.5
N8	0.8%	35.9	12.3	9.0	103.6	344.2	341.5	3.6
TOTAL	100.0%	374.0	148.5	207.2	1077.7	4899.3	4863.0	55.9
EPA switch duty cycle weighted brake-specific emissions			0.397	0.55	2.88	13.10	13.00	0.15
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

UP #9733 Test Date 5-25-99 CARB Diesel Fuel EM-2663-F Run #3/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	22	44.0	208	319	1,079	1,066	34
Low Idle	16	15.2	125	123	289	286	12
Idle	10	21.0	118	159	554	548	15
N1	192	81.0	111	119	1,840	1,822	34
N2	498	189.0	147	330	5,153	5,109	61
N3	1,033	387.0	368	1,900	14,703	14,543	135
N4	1,548	571.0	349	7,428	22,045	21,785	213
N5	2,221	790.0	539	10,011	29,313	29,047	264
N6	2,938	1,005.0	722	10,835	36,127	35,766	267
N7	3,663	1,240.0	804	14,194	41,478	41,046	325
N8	4,499	1,545.0	1,016	14,858	43,196	42,860	538
							sum =

Weighted Results

Notch	EPA Line-Haul WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.8	5.5	26.0	39.9	134.9	133.2	4.3
Low Idle	19.0%	3.0	2.9	23.8	23.4	54.9	54.3	2.3
Idle	19.0%	1.9	4.0	22.4	30.2	105.3	104.1	2.9
N1	6.5%	12.5	5.3	7.2	7.7	119.6	118.4	2.2
N2	6.5%	32.4	12.3	9.6	21.5	334.9	332.1	4.0
N3	5.2%	53.7	20.1	19.1	98.8	764.6	756.2	7.0
N4	4.4%	68.1	25.1	15.4	326.8	970.0	958.5	9.4
N5	3.8%	84.4	30.0	20.5	380.4	1113.9	1103.8	10.0
N6	3.9%	114.6	39.2	28.2	422.6	1409.0	1394.9	10.4
N7	3.0%	109.9	37.2	24.1	425.8	1244.3	1231.4	9.8
N8	16.2%	728.8	250.3	164.6	2407.0	6997.8	6943.4	87.2
TOTAL	100.0%	1212.1	431.9	360.8	4184.1	13249.1	13130.3	149.3
EPA line-haul duty cycle weighted brake-specific emissions			0.356	0.30	3.5	**10.9**	**10.8**	0.12
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	2.000	9.45	14.50	49.05	48.45	1.55
Low Idle	0.950	7.81	7.69	18.06	17.85	0.75
Idle	2.100	11.80	15.90	55.40	54.80	1.50
N1	0.422	0.58	0.62	9.58	9.49	0.18
N2	0.380	0.30	0.66	10.35	10.26	0.12
N3	0.375	0.36	1.84	14.23	14.08	0.13
N4	0.369	0.23	4.80	14.24	14.07	0.14
N5	0.356	0.24	4.51	13.20	13.08	0.12
N6	0.342	0.25	3.69	12.30	12.17	0.09
N7	0.339	0.22	3.87	11.32	11.21	0.09
N8	0.343	0.23	3.30	9.60	9.53	0.12

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	4.8	4.5	37.4	36.8	86.4	85.4	3.6
Idle	29.9%	3.0	6.3	35.3	47.5	165.6	163.8	4.5
N1	12.4%	23.8	10.0	13.8	14.8	228.2	225.9	4.2
N2	12.3%	61.3	23.2	18.1	40.6	633.8	628.4	7.5
N3	5.8%	59.9	22.4	21.3	110.2	852.8	843.5	7.8
N4	3.6%	55.7	20.6	12.6	267.4	793.6	784.3	7.7
N5	3.6%	80.0	28.4	19.4	360.4	1055.3	1045.7	9.5
N6	1.5%	44.1	15.1	10.8	162.5	541.9	536.5	4.0
N7	0.2%	7.3	2.5	1.6	28.4	83.0	82.1	0.7
N8	0.8%	36.0	12.4	8.1	118.9	345.6	342.9	4.3
TOTAL	100.0%	375.8	145.5	178.4	1187.4	4786.1	4738.5	53.8
EPA switch duty cycle weighted brake-specific emissions			0.387	0.47	3.16	12.74	12.61	0.14
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

APPENDIX F-3

UP No. 9733 Test Results Using On-Highway Diesel Fuel

UP #9733 Test Date 5-18-99 On-Highway Diesel Fuel EM-2677-F Run #2/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	22	41.3	195	331	1,044	1,034	35
Low Idle	16	20.0	164	163	421	417	18
Idle	10	27.0	164	240	708	703	20
N1	201	83.0	121	103	2,030	2,013	35
N2	497	188.0	152	260	5,324	5,277	62
N3	1,035	392.0	368	1,436	15,182	15,056	137
N4	1,552	578.0	335	7,188	22,606	22,435	179
N5	2,223	797.0	589	10,141	31,127	30,859	260
N6	2,942	1,016.0	746	11,050	37,947	37,663	280
N7	3,664	1,241.0	858	11,836	42,057	41,739	330
N8	4,504	1,554.0	1,059	14,956	42,943	42,660	575
						sum =	

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.8	5.2	24.4	41.4	130.5	129.2	4.4
Low Idle	19.0%	3.0	3.8	31.2	31.0	80.0	79.3	3.4
Idle	19.0%	1.9	5.1	31.2	45.6	134.5	133.5	3.8
N1	6.5%	13.1	5.4	7.9	6.7	132.0	130.8	2.3
N2	6.5%	32.3	12.2	9.9	16.9	346.1	343.0	4.0
N3	5.2%	53.8	20.4	19.1	74.7	789.5	782.9	7.1
N4	4.4%	68.3	25.4	14.7	316.3	994.7	987.1	7.9
N5	3.8%	84.5	30.3	22.4	385.4	1182.8	1172.6	9.9
N6	3.9%	114.7	39.6	29.1	431.0	1479.9	1468.9	10.9
N7	3.0%	109.9	37.2	25.7	355.1	1261.7	1252.2	9.9
N8	16.2%	729.6	251.7	171.6	2422.9	6956.8	6910.9	93.2
TOTAL	100.0%	1213.9	436.4	387.1	4126.7	13488.4	13390.4	156.8
EPA line-haul duty cycle weighted brake-specific emissions			0.359	0.32	3.4	**11.1**	**11.0**	0.13
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	1.877	8.86	15.05	47.45	46.99	1.59
Low Idle	1.250	10.25	10.19	26.31	26.08	1.13
Idle	2.700	16.40	24.00	70.80	70.27	2.00
N1	0.413	0.60	0.51	10.10	10.01	0.17
N2	0.378	0.31	0.52	10.71	10.62	0.12
N3	0.379	0.36	1.39	14.67	14.55	0.13
N4	0.372	0.22	4.63	14.57	14.46	0.12
N5	0.359	0.26	4.56	14.00	13.88	0.12
N6	0.345	0.25	3.76	12.90	12.80	0.10
N7	0.339	0.23	3.23	11.48	11.39	0.09
N8	0.345	0.24	3.32	9.53	9.47	0.13

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	4.8	6.0	49.0	48.7	125.9	124.7	5.4
Idle	29.9%	3.0	8.1	49.0	71.8	211.7	210.1	6.0
N1	12.4%	24.9	10.3	15.0	12.8	251.7	249.6	4.3
N2	12.3%	61.1	23.1	18.7	32.0	654.9	649.0	7.6
N3	5.8%	60.0	22.7	21.3	83.3	880.6	873.3	7.9
N4	3.6%	55.9	20.8	12.1	258.8	813.8	807.6	6.4
N5	3.6%	80.0	28.7	21.2	365.1	1120.6	1110.9	9.4
N6	1.5%	44.1	15.2	11.2	165.8	569.2	564.9	4.2
N7	0.2%	7.3	2.5	1.7	23.7	84.1	83.5	0.7
N8	0.8%	36.0	12.4	8.5	119.6	343.5	341.3	4.6
TOTAL	100.0%	377.2	149.9	207.8	1181.5	5055.9	5015.0	56.5
EPA switch duty cycle weighted brake-specific emissions			0.397	0.55	3.13	13.40	13.29	0.15
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

UP #9733 Test Date 5-19-99 On-Highway Diesel Fuel EM-2677-F Run #2/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	23	45.0	233	401	1,115	1,107	41
Low Idle	10	22.0	223	210	443	440	23
Idle	10	25.8	156	246	678	672	25
N1	190	80.0	123	114	2,052	2,035	48
N2	497	188.0	196	303	5,509	5,461	92
N3	1,038	393.0	353	1,465	15,576	15,447	138
N4	1,549	573.0	426	5,625	23,241	23,036	193
N5	2,224	795.0	603	9,223	29,858	29,613	260
N6	2,941	1,011.0	716	10,240	35,634	35,325	275
N7	3,665	1,241.0	903	10,945	44,120	43,697	308
N8	4,506	1,547.0	1,040	13,672	43,897	43,518	527
						sum =	

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.9	5.6	29.1	50.1	139.4	138.4	5.1
Low Idle	19.0%	1.9	4.2	42.4	39.9	84.2	83.6	4.4
Idle	19.0%	1.9	4.9	29.6	46.7	128.8	127.7	4.8
N1	6.5%	12.4	5.2	8.0	7.4	133.4	132.3	3.1
N2	6.5%	32.3	12.2	12.7	19.7	358.1	355.0	6.0
N3	5.2%	54.0	20.4	18.4	76.2	810.0	803.2	7.2
N4	4.4%	68.2	25.2	18.7	247.5	1022.6	1013.6	8.5
N5	3.8%	84.5	30.2	22.9	350.5	1134.6	1125.3	9.9
N6	3.9%	114.7	39.4	27.9	399.4	1389.7	1377.7	10.7
N7	3.0%	110.0	37.2	27.1	328.4	1323.6	1310.9	9.2
N8	16.2%	730.0	250.6	168.5	2214.9	7111.3	7049.9	85.4
TOTAL	100.0%	1212.6	435.3	405.4	3780.6	13635.6	13517.5	154.2
EPA line-haul duty cycle weighted brake-specific emissions			0.359	0.33	3.1	**11.2**	**11.1**	0.13
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	1.957	10.13	17.43	48.48	48.15	1.78
Low Idle	2.200	22.30	21.00	44.30	44.00	2.30
Idle	2.580	15.60	24.60	67.80	67.23	2.50
N1	0.421	0.65	0.60	10.80	10.71	0.25
N2	0.378	0.39	0.61	11.08	10.99	0.19
N3	0.379	0.34	1.41	15.01	14.88	0.13
N4	0.370	0.28	3.63	15.00	14.87	0.12
N5	0.357	0.27	4.15	13.43	13.32	0.12
N6	0.344	0.24	3.48	12.12	12.01	0.09
N7	0.339	0.25	2.99	12.04	11.92	0.08
N8	0.343	0.23	3.03	9.74	9.66	0.12

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	3.0	6.6	66.7	62.8	132.5	131.6	6.9
Idle	29.9%	3.0	7.7	46.6	73.6	202.7	201.0	7.5
N1	12.4%	23.6	9.9	15.3	14.1	254.4	252.3	6.0
N2	12.3%	61.1	23.1	24.1	37.3	677.6	671.7	11.3
N3	5.8%	60.2	22.8	20.5	85.0	903.4	895.9	8.0
N4	3.6%	55.8	20.6	15.3	202.5	836.7	829.3	6.9
N5	3.6%	80.1	28.6	21.7	332.0	1074.9	1066.1	9.4
N6	1.5%	44.1	15.2	10.7	153.6	534.5	529.9	4.1
N7	0.2%	7.3	2.5	1.8	21.9	88.2	87.4	0.6
N8	0.8%	36.0	12.4	8.3	109.4	351.2	348.1	4.2
TOTAL	100.0%	374.2	149.4	231.1	1092.1	5056.1	5013.3	64.9
EPA switch duty cycle weighted brake-specific emissions			0.399	0.62	2.92	13.51	13.40	0.17
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

UP #9733 Test Date 5-24-99 On-Highway Diesel Fuel EM-2677-F Run #3/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	30	43.0	207	361	1,075	1,060	35
Low Idle	10	18.9	190	182	357	352	21
Idle	10	25.2	149	239	664	655	20
N1	194	80.0	113	115	2,043	2,016	35
N2	497	191.0	159	333	5,578	5,494	70
N3	1,035	399.0	352	1,881	15,871	15,654	150
N4	1,549	577.0	352	7,084	23,263	22,937	210
N5	2,222	808.0	516	11,413	29,920	29,493	299
N6	2,938	1,024.0	715	13,942	37,278	36,727	340
N7	3,664	1,260.0	837	14,085	42,064	41,493	387
N8	4,325	1,508.0	938	16,147	42,236	41,667	565
						sum =	

Weighted Results

Notch	EPA Line-Haul WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	3.8	5.4	25.9	45.1	134.4	132.6	4.4
Low Idle	19.0%	1.9	3.6	36.1	34.6	67.8	66.8	4.0
Idle	19.0%	1.9	4.8	28.3	45.4	126.2	124.4	3.8
N1	6.5%	12.6	5.2	7.3	7.5	132.8	131.0	2.3
N2	6.5%	32.3	12.4	10.3	21.6	362.6	357.1	4.6
N3	5.2%	53.8	20.7	18.3	97.8	825.3	814.0	7.8
N4	4.4%	68.2	25.4	15.5	311.7	1023.6	1009.2	9.2
N5	3.8%	84.4	30.7	19.6	433.7	1137.0	1120.7	11.4
N6	3.9%	114.6	39.9	27.9	543.7	1453.8	1432.4	13.3
N7	3.0%	109.9	37.8	25.1	422.6	1261.9	1244.8	11.6
N8	16.2%	700.7	244.3	152.0	2615.8	6842.2	6750.1	91.5
TOTAL	100.0%	1184.0	430.2	366.3	4579.5	13367.5	13183.3	163.8
EPA line-haul duty cycle weighted brake-specific emissions			0.363	0.31	3.9	**11.3**	**11.1**	0.14
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	1.433	6.90	12.03	35.83	35.35	1.17
Low Idle	1.890	19.00	18.20	35.70	35.16	2.10
Idle	2.520	14.90	23.90	66.40	65.50	2.00
N1	0.412	0.58	0.59	10.53	10.39	0.18
N2	0.384	0.32	0.67	11.22	11.05	0.14
N3	0.386	0.34	1.82	15.33	15.12	0.14
N4	0.372	0.23	4.57	15.02	14.81	0.14
N5	0.364	0.23	5.14	13.47	13.27	0.13
N6	0.349	0.24	4.75	12.69	12.50	0.12
N7	0.344	0.23	3.84	11.48	11.32	0.11
N8	0.349	0.22	3.73	9.77	9.63	0.13

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	3.0	5.7	56.8	54.4	106.7	105.1	6.3
Idle	29.9%	3.0	7.5	44.6	71.5	198.5	195.8	6.0
N1	12.4%	24.1	9.9	14.0	14.3	253.3	250.0	4.3
N2	12.3%	61.1	23.5	19.6	41.0	686.1	675.8	8.6
N3	5.8%	60.0	23.1	20.4	109.1	920.5	907.9	8.7
N4	3.6%	55.8	20.8	12.7	255.0	837.5	825.7	7.6
N5	3.6%	80.0	29.1	18.6	410.9	1077.1	1061.8	10.8
N6	1.5%	44.1	15.4	10.7	209.1	559.2	550.9	5.1
N7	0.2%	7.3	2.5	1.7	28.2	84.1	83.0	0.8
N8	0.8%	34.6	12.1	7.5	129.2	337.9	333.3	4.5
TOTAL	100.0%	373.0	149.5	206.5	1322.6	5061.0	4989.4	62.6
EPA switch duty cycle weighted brake-specific emissions			0.401	0.55	3.55	13.57	13.38	0.17
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

APPENDIX F-4

UP No. 9733 Test Results Using High-Sulfur Diesel Fuel

UP #9733 Test Date 5-20-99 Nonroad High-Sulfur Diesel Fuel EM-2664-F Run #1/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	30	41.3	186	357	1,060	1,049	39
Low Idle	10	19.0	175	198	340	337	31
Idle	10	24.0	137	239	643	637	27
N1	194	81.0	127	120	2,244	2,229	60
N2	498	190.0	174	294	5,877	5,834	125
N3	1,037	398.0	355	1,623	15,882	15,773	243
N4	1,552	575.0	377	5,933	23,347	23,174	343
N5	2,220	803.0	526	10,014	31,526	31,309	407
N6	2,940	1,021.0	703	13,067	38,338	38,045	445
N7	3,663	1,249.0	796	13,034	42,486	42,136	565
N8	4,493	1,555.0	961	15,247	45,379	45,043	906
						sum =	

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	3.8	5.2	23.3	44.6	132.5	131.2	4.9
Low Idle	19.0%	1.9	3.6	33.3	37.6	64.6	64.0	5.9
Idle	19.0%	1.9	4.6	26.0	45.4	122.2	121.1	5.1
N1	6.5%	12.6	5.3	8.3	7.8	145.9	144.9	3.9
N2	6.5%	32.4	12.4	11.3	19.1	382.0	379.2	8.1
N3	5.2%	53.9	20.7	18.5	84.4	825.9	820.2	12.6
N4	4.4%	68.3	25.3	16.6	261.1	1027.3	1019.7	15.1
N5	3.8%	84.4	30.5	20.0	380.5	1198.0	1189.7	15.5
N6	3.9%	114.7	39.8	27.4	509.6	1495.2	1483.8	17.4
N7	3.0%	109.9	37.5	23.9	391.0	1274.6	1264.1	17.0
N8	16.2%	727.9	251.9	155.7	2470.0	7351.4	7297.0	146.8
TOTAL	100.0%	1211.5	436.7	364.1	4251.2	14019.4	13914.8	252.2
EPA line-haul duty cycle weighted brake-specific emissions			0.360	0.30	3.5	**11.6**	**11.5**	0.21
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	1.377	6.20	11.90	35.33	34.98	1.30
Low Idle	1.900	17.50	19.80	34.00	33.70	3.10
Idle	2.400	13.70	23.90	64.30	63.75	2.70
N1	0.418	0.65	0.62	11.57	11.49	0.31
N2	0.382	0.35	0.59	11.80	11.71	0.25
N3	0.384	0.34	1.57	15.32	15.21	0.23
N4	0.370	0.24	3.82	15.04	14.93	0.22
N5	0.362	0.24	4.51	14.20	14.10	0.18
N6	0.347	0.24	4.44	13.04	12.94	0.15
N7	0.341	0.22	3.56	11.60	11.50	0.15
N8	0.346	0.21	3.39	10.10	10.03	0.20

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	3.0	5.7	52.3	59.2	101.7	100.8	9.3
Idle	29.9%	3.0	7.2	41.0	71.5	192.3	190.6	8.1
N1	12.4%	24.1	10.0	15.7	14.9	278.3	276.4	7.4
N2	12.3%	61.3	23.4	21.4	36.2	722.9	717.6	15.4
N3	5.8%	60.1	23.1	20.6	94.1	921.2	914.8	14.1
N4	3.6%	55.9	20.7	13.6	213.6	840.5	834.3	12.3
N5	3.6%	79.9	28.9	18.9	360.5	1134.9	1127.1	14.7
N6	1.5%	44.1	15.3	10.5	196.0	575.1	570.7	6.7
N7	0.2%	7.3	2.5	1.6	26.1	85.0	84.3	1.1
N8	0.8%	35.9	12.4	7.7	122.0	363.0	360.3	7.2
TOTAL	100.0%	374.6	149.2	203.4	1194.0	5214.7	5176.8	96.3
EPA switch duty cycle weighted brake-specific emissions			0.398	0.54	3.19	13.92	13.82	0.26
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

UP #9733 Test Date 5-21-99 Nonroad High-Sulfur Diesel Fuel EM-2664-F Run #2/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	22	42.3	181	366	1,092	1,072	37
Low Idle	10	16.8	148	176	303	297	23
Idle	10	26.4	159	270	714	701	29
N1	193	82.0	119	115	2,275	2,241	51
N2	499	190.0	163	305	5,921	5,831	108
N3	1,034	396.0	336	997	16,536	16,293	270
N4	1,551	577.0	371	5,292	23,736	23,413	357
N5	2,223	805.0	535	9,968	31,407	31,003	459
N6	2,939	1,021.0	669	12,724	37,102	36,610	500
N7	3,664	1,251.0	831	13,802	45,783	45,172	567
N8	4,496	1,559.0	931	15,592	45,794	45,206	847
							sum =

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.8	5.3	22.6	45.8	136.5	134.0	4.6
Low Idle	19.0%	1.9	3.2	28.1	33.4	57.6	56.5	4.4
Idle	19.0%	1.9	5.0	30.2	51.3	135.7	133.2	5.5
N1	6.5%	12.5	5.3	7.7	7.5	147.9	145.7	3.3
N2	6.5%	32.4	12.4	10.6	19.8	384.9	379.0	7.0
N3	5.2%	53.8	20.6	17.5	51.8	859.9	847.3	14.0
N4	4.4%	68.2	25.4	16.3	232.8	1044.4	1030.2	15.7
N5	3.8%	84.5	30.6	20.3	378.8	1193.5	1178.1	17.4
N6	3.9%	114.6	39.8	26.1	496.2	1447.0	1427.8	19.5
N7	3.0%	109.9	37.5	24.9	414.1	1373.5	1355.2	17.0
N8	16.2%	728.4	252.6	150.8	2525.9	7418.6	7323.4	137.2
TOTAL	100.0%	1210.9	437.7	355.3	4257.5	14199.3	14010.3	245.8
EPA line-haul duty cycle weighted brake-specific emissions			0.361	0.29	3.5	**11.7**	**11.6**	0.20
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	1.923	8.23	16.64	49.64	48.74	1.68
Low Idle	1.680	14.80	17.60	30.30	29.72	2.30
Idle	2.640	15.90	27.00	71.40	70.10	2.90
N1	0.425	0.62	0.60	11.79	11.61	0.26
N2	0.381	0.33	0.61	11.87	11.69	0.22
N3	0.383	0.32	0.96	15.99	15.76	0.26
N4	0.372	0.24	3.41	15.30	15.10	0.23
N5	0.362	0.24	4.48	14.13	13.95	0.21
N6	0.347	0.23	4.33	12.62	12.46	0.17
N7	0.341	0.23	3.77	12.50	12.33	0.15
N8	0.347	0.21	3.47	10.19	10.05	0.19

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	3.0	5.0	44.3	52.6	90.6	88.9	6.9
Idle	29.9%	3.0	7.9	47.5	80.7	213.5	209.6	8.7
N1	12.4%	23.9	10.2	14.8	14.3	282.1	277.9	6.3
N2	12.3%	61.4	23.4	20.0	37.5	728.3	717.2	13.3
N3	5.8%	60.0	23.0	19.5	57.8	959.1	945.0	15.7
N4	3.6%	55.8	20.8	13.4	190.5	854.5	842.9	12.9
N5	3.6%	80.0	29.0	19.3	358.8	1130.7	1116.1	16.5
N6	1.5%	44.1	15.3	10.0	190.9	556.5	549.2	7.5
N7	0.2%	7.3	2.5	1.7	27.6	91.6	90.3	1.1
N8	0.8%	36.0	12.5	7.4	124.7	366.4	361.6	6.8
TOTAL	100.0%	374.5	149.5	197.8	1135.5	5273.2	5198.8	95.6
EPA switch duty cycle weighted brake-specific emissions			0.399	0.53	3.03	14.08	13.88	0.26
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

UP #9733 Test Date 5-21-99 Nonroad High Sulfur Diesel Fuel EM-2664-F Run #3/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	22	43.0	181	372	1,095	1,084	32
Low Idle	16	19.5	180	194	348	344	25
Idle	10	23.4	142	237	632	625	23
N1	194	83.0	113	124	2,259	2,240	41
N2	498	191.0	164	319	5,798	5,746	93
N3	1,037	397.0	335	1,772	16,086	15,950	246
N4	1,547	573.0	333	5,997	23,497	23,281	298
N5	2,221	807.0	502	10,568	30,755	30,484	428
N6	2,938	1,021.0	704	13,007	36,892	36,590	448
N7	3,663	1,250.0	797	12,858	43,678	43,308	528
N8	4,495	1,557.0	1,035	15,693	46,297	45,951	888
							sum =

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.8	5.4	22.6	46.5	136.9	135.5	4.0
Low Idle	19.0%	3.0	3.7	34.2	36.9	66.1	65.3	4.8
Idle	19.0%	1.9	4.4	27.0	45.0	120.1	118.8	4.4
N1	6.5%	12.6	5.4	7.3	8.1	146.8	145.6	2.7
N2	6.5%	32.4	12.4	10.7	20.7	376.9	373.5	6.0
N3	5.2%	53.9	20.6	17.4	92.1	836.5	829.4	12.8
N4	4.4%	68.1	25.2	14.7	263.9	1033.9	1024.3	13.1
N5	3.8%	84.4	30.7	19.1	401.6	1168.7	1158.4	16.3
N6	3.9%	114.6	39.8	27.5	507.3	1438.8	1427.0	17.5
N7	3.0%	109.9	37.5	23.9	385.7	1310.3	1299.2	15.8
N8	16.2%	728.2	252.2	167.7	2542.3	7500.1	7444.1	143.9
TOTAL	100.0%	1211.7	437.4	372.0	4350.1	14135.1	14021.2	241.2
EPA line-haul duty cycle weighted brake-specific emissions			0.361	0.31	3.6	**11.7**	**11.6**	0.20
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	1.955	8.23	16.91	49.77	49.26	1.45
Low Idle	1.219	11.25	12.13	21.75	21.50	1.56
Idle	2.340	14.20	23.70	63.20	62.50	2.30
N1	0.428	0.58	0.64	11.64	11.54	0.21
N2	0.384	0.33	0.64	11.64	11.54	0.19
N3	0.383	0.32	1.71	15.51	15.38	0.24
N4	0.370	0.22	3.88	15.19	15.05	0.19
N5	0.363	0.23	4.76	13.85	13.73	0.19
N6	0.348	0.24	4.43	12.56	12.45	0.15
N7	0.341	0.22	3.51	11.92	11.82	0.14
N8	0.346	0.23	3.49	10.30	10.22	0.20

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	4.8	5.8	53.8	58.0	104.1	102.8	7.5
Idle	29.9%	3.0	7.0	42.5	70.9	189.0	186.9	6.9
N1	12.4%	24.1	10.3	14.0	15.4	280.1	277.7	5.1
N2	12.3%	61.3	23.5	20.2	39.2	713.2	706.8	11.4
N3	5.8%	60.1	23.0	19.4	102.8	933.0	925.1	14.3
N4	3.6%	55.7	20.6	12.0	215.9	845.9	838.1	10.7
N5	3.6%	80.0	29.1	18.1	380.4	1107.2	1097.4	15.4
N6	1.5%	44.1	15.3	10.6	195.1	553.4	548.9	6.7
N7	0.2%	7.3	2.5	1.6	25.7	87.4	86.6	1.1
N8	0.8%	36.0	12.5	8.3	125.5	370.4	367.6	7.1
TOTAL	100.0%	376.2	149.6	200.4	1229.0	5183.5	5138.0	86.2
EPA switch duty cycle weighted brake-specific emissions			0.398	0.53	3.27	13.78	13.66	0.23
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

APPENDIX F-5

UP No. 9733 Test Results Using 0.3% Sulfur Diesel Fuel

UP #9733 Test Date 5-19-99 0.3% Diesel Fuel EM-2708-F Run #1/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	22	39.0	185	348	975	965	45
Low Idle	10	19.0	220	202	304	301	30
Idle	10	24.0	140	223	603	598	23
N1	194	82.0	129	116	2,267	2,248	46
N2	497	191.0	182	307	5,833	5,791	87
N3	1,030	396.0	429	1,628	16,185	16,073	192
N4	1,550	576.0	405	5,999	24,196	24,046	218
N5	2,224	801.0	552	9,751	30,977	30,761	291
N6	2,938	1,018.0	739	11,353	37,197	37,040	347
N7	3,663	1,250.0	820	12,459	42,636	42,380	404
N8	4,500	1,558.0	947	15,572	44,740	44,465	725
						sum =	

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.8	4.9	23.1	43.5	121.9	120.6	5.6
Low Idle	19.0%	1.9	3.6	41.8	38.4	57.8	57.2	5.7
Idle	19.0%	1.9	4.6	26.6	42.4	114.6	113.5	4.4
N1	6.5%	12.6	5.3	8.4	7.5	147.4	146.1	3.0
N2	6.5%	32.3	12.4	11.8	20.0	379.1	376.4	5.7
N3	5.2%	53.6	20.6	22.3	84.7	841.6	835.8	10.0
N4	4.4%	68.2	25.3	17.8	264.0	1064.6	1058.0	9.6
N5	3.8%	84.5	30.4	21.0	370.5	1177.1	1168.9	11.1
N6	3.9%	114.6	39.7	28.8	442.8	1450.7	1444.6	13.5
N7	3.0%	109.9	37.5	24.6	373.8	1279.1	1271.4	12.1
N8	16.2%	729.0	252.4	153.4	2522.7	7247.9	7203.4	117.5
TOTAL	100.0%	1211.2	436.8	379.7	4210.1	13881.7	13796.0	198.1
EPA line-haul duty cycle weighted brake-specific emissions			0.361	0.31	3.5	**11.5**	**11.4**	0.16
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	1.773	8.41	15.82	44.32	43.87	2.05
Low Idle	1.900	22.00	20.20	30.40	30.13	3.00
Idle	2.400	14.00	22.30	60.30	59.75	2.30
N1	0.423	0.66	0.60	11.69	11.59	0.24
N2	0.384	0.37	0.62	11.74	11.65	0.18
N3	0.384	0.42	1.58	15.71	15.61	0.19
N4	0.372	0.26	3.87	15.61	15.51	0.14
N5	0.360	0.25	4.38	13.93	13.83	0.13
N6	0.346	0.25	3.86	12.66	12.61	0.12
N7	0.341	0.22	3.40	11.64	11.57	0.11
N8	0.346	0.21	3.46	9.94	9.88	0.16

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	3.0	5.7	65.8	60.4	90.9	90.1	9.0
Idle	29.9%	3.0	7.2	41.9	66.7	180.3	178.7	6.9
N1	12.4%	24.1	10.2	16.0	14.4	281.1	278.7	5.7
N2	12.3%	61.1	23.5	22.4	37.8	717.5	712.3	10.7
N3	5.8%	59.7	23.0	24.9	94.4	938.7	932.3	11.1
N4	3.6%	55.8	20.7	14.6	216.0	871.1	865.7	7.8
N5	3.6%	80.1	28.8	19.9	351.0	1115.2	1107.4	10.5
N6	1.5%	44.1	15.3	11.1	170.3	558.0	555.6	5.2
N7	0.2%	7.3	2.5	1.6	24.9	85.3	84.8	0.8
N8	0.8%	36.0	12.5	7.6	124.6	357.9	355.7	5.8
TOTAL	100.0%	374.2	149.3	225.7	1160.4	5195.9	5161.1	73.5
EPA switch duty cycle weighted brake-specific emissions			0.399	0.60	3.10	13.89	13.79	0.20
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

UP #9733 Test Date 5-20-99 0.3% Diesel Fuel EM-2708-F Run #2/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	22	41.3	182	376	1,024	1,009	35
Low Idle	10	19.5	206	208	335	330	28
Idle	10	24.0	152	247	637	627	23
N1	194	80.0	113	109	2,166	2,135	38
N2	499	191.0	170	291	5,821	5,736	89
N3	1,032	398.0	354	1,437	16,361	16,140	202
N4	1,548	574.0	395	4,935	24,093	23,822	264
N5	2,222	803.0	514	9,282	31,869	31,504	344
N6	2,939	1,020.0	679	11,669	36,589	36,148	405
N7	3,662	1,251.0	799	12,285	42,567	42,075	448
N8	4,496	1,564.0	964	15,485	45,669	45,195	748
						sum =	

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.8	5.2	22.8	47.0	128.0	126.1	4.4
Low Idle	19.0%	1.9	3.7	39.1	39.5	63.7	62.7	5.3
Idle	19.0%	1.9	4.6	28.9	46.9	121.0	119.1	4.4
N1	6.5%	12.6	5.2	7.3	7.1	140.8	138.8	2.5
N2	6.5%	32.4	12.4	11.1	18.9	378.4	372.9	5.8
N3	5.2%	53.7	20.7	18.4	74.7	850.8	839.3	10.5
N4	4.4%	68.1	25.3	17.4	217.1	1060.1	1048.2	11.6
N5	3.8%	84.4	30.5	19.5	352.7	1211.0	1197.2	13.1
N6	3.9%	114.6	39.8	26.5	455.1	1427.0	1409.8	15.8
N7	3.0%	109.9	37.5	24.0	368.6	1277.0	1262.3	13.4
N8	16.2%	728.4	253.4	156.2	2508.6	7398.4	7321.6	121.2
TOTAL	100.0%	1210.6	438.2	371.1	4136.2	14056.1	13897.9	207.9
EPA line-haul duty cycle weighted brake-specific emissions			0.362	0.31	3.4	**11.6**	**11.5**	0.17
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	1.877	8.27	17.09	46.55	45.87	1.59
Low Idle	1.950	20.60	20.80	33.50	33.01	2.80
Idle	2.400	15.20	24.70	63.70	62.69	2.30
N1	0.412	0.58	0.56	11.16	11.01	0.20
N2	0.383	0.34	0.58	11.67	11.50	0.18
N3	0.386	0.34	1.39	15.85	15.64	0.20
N4	0.371	0.26	3.19	15.56	15.39	0.17
N5	0.361	0.23	4.18	14.34	14.18	0.15
N6	0.347	0.23	3.97	12.45	12.30	0.14
N7	0.342	0.22	3.35	11.62	11.49	0.12
N8	0.348	0.21	3.44	10.16	10.05	0.17

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	3.0	5.8	61.6	62.2	100.2	98.7	8.4
Idle	29.9%	3.0	7.2	45.4	73.9	190.5	187.4	6.9
N1	12.4%	24.1	9.9	14.0	13.5	268.6	264.7	4.7
N2	12.3%	61.4	23.5	20.9	35.8	716.0	705.6	10.9
N3	5.8%	59.9	23.1	20.5	83.3	948.9	936.1	11.7
N4	3.6%	55.7	20.7	14.2	177.7	867.3	857.6	9.5
N5	3.6%	80.0	28.9	18.5	334.2	1147.3	1134.2	12.4
N6	1.5%	44.1	15.3	10.2	175.0	548.8	542.2	6.1
N7	0.2%	7.3	2.5	1.6	24.6	85.1	84.2	0.9
N8	0.8%	36.0	12.5	7.7	123.9	365.4	361.6	6.0
TOTAL	100.0%	374.4	149.4	214.7	1104.0	5238.1	5172.2	77.5
EPA switch duty cycle weighted brake-specific emissions			0.399	0.57	2.95	13.99	13.82	0.21
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

UP #9733 Test Date 5-24-99 0.3% Diesel Fuel EM-2708-F Run #3/3

SwRI Project 08-2062-001

Notch	flywheel HP	fuel rate (lb/hr)	HC (g/hr)	CO (g/hr)	Corr. NOx (g/hr)	KH-NOx (g/hr)	PM (g/hr)
DB-2	22	44.0	197	388	1,108	1,092	36
Low Idle	10	17.6	187	175	304	300	24
Idle	10	24.6	154	233	657	647	24
N1	193	83.0	114	110	2,249	2,219	40
N2	500	192.0	158	295	5,923	5,841	88
N3	1,031	400.0	310	1,562	15,817	15,603	183
N4	1,549	573.0	347	5,502	23,755	23,412	301
N5	2,222	810.0	492	11,705	30,632	30,209	403
N6	2,939	1,029.0	666	14,347	36,139	35,653	475
N7	3,665	1,253.0	834	12,955	43,286	42,763	479
N8	4,501	1,559.0	971	15,166	45,384	44,785	761
						sum =	

Weighted Results

EPA Line-Haul

Notch	WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	12.5%	2.8	5.5	24.6	48.5	138.5	136.5	4.5
Low Idle	19.0%	1.9	3.3	35.5	33.3	57.8	57.1	4.6
Idle	19.0%	1.9	4.7	29.3	44.3	124.8	122.9	4.6
N1	6.5%	12.5	5.4	7.4	7.2	146.2	144.2	2.6
N2	6.5%	32.5	12.5	10.3	19.2	385.0	379.7	5.7
N3	5.2%	53.6	20.8	16.1	81.2	822.5	811.3	9.5
N4	4.4%	68.2	25.2	15.3	242.1	1045.2	1030.1	13.2
N5	3.8%	84.4	30.8	18.7	444.8	1164.0	1147.9	15.3
N6	3.9%	114.6	40.1	26.0	559.5	1409.4	1390.5	18.5
N7	3.0%	110.0	37.6	25.0	388.7	1298.6	1282.9	14.4
N8	16.2%	729.2	252.6	157.3	2456.9	7352.2	7255.2	123.3
TOTAL	100.0%	1211.5	438.5	365.5	4325.5	13944.2	13758.2	216.2
EPA line-haul duty cycle weighted brake-specific emissions			0.362	0.30	3.6	**11.5**	**11.4**	0.18
EPA line-haul duty cycle maximum Tier 0				1.00	5.0	9.5	9.5	0.60

Individual Notch brake-specific emissions

Notch	bsfc (lb/hp-hr)	HC (g/hp-hr)	CO (g/hp-hr)	Corr. NOx (g/hp-hr)	KH-NOx (g/hp-hr)	PM (g/hp-hr)
DB-2	2.000	8.95	17.64	50.36	49.62	1.64
Low Idle	1.760	18.70	17.50	30.40	30.03	2.40
Idle	2.460	15.40	23.30	65.70	64.69	2.40
N1	0.430	0.59	0.57	11.65	11.50	0.21
N2	0.384	0.32	0.59	11.85	11.68	0.18
N3	0.388	0.30	1.52	15.34	15.13	0.18
N4	0.370	0.22	3.55	15.34	15.11	0.19
N5	0.365	0.22	5.27	13.79	13.60	0.18
N6	0.350	0.23	4.88	12.30	12.13	0.16
N7	0.342	0.23	3.53	11.81	11.67	0.13
N8	0.346	0.22	3.37	10.08	9.95	0.17

EPA Switch Cycle

Weighted Results

Notch	EPA WF	w-BHP	w-bsfc w-(lb/hp-hr)	w-HC w-(g/hr)	w-CO w-(g/hr)	w-NOx w-(g/hr)	w-KH-NOx w-(g/hr)	w-PM w-(g/hr)
DB-2	0.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Low Idle	29.9%	3.0	5.3	55.9	52.3	90.9	89.8	7.2
Idle	29.9%	3.0	7.4	46.0	69.7	196.4	193.4	7.2
N1	12.4%	23.9	10.3	14.1	13.6	278.9	275.1	5.0
N2	12.3%	61.5	23.6	19.4	36.3	728.5	718.5	10.8
N3	5.8%	59.8	23.2	18.0	90.6	917.4	904.9	10.6
N4	3.6%	55.8	20.6	12.5	198.1	855.2	842.8	10.8
N5	3.6%	80.0	29.2	17.7	421.4	1102.8	1087.5	14.5
N6	1.5%	44.1	15.4	10.0	215.2	542.1	534.8	7.1
N7	0.2%	7.3	2.5	1.7	25.9	86.6	85.5	1.0
N8	0.8%	36.0	12.5	7.8	121.3	363.1	358.3	6.1
TOTAL	100.0%	374.4	149.9	203.1	1244.4	5161.8	5090.7	80.3
EPA switch duty cycle weighted brake-specific emissions			0.400	0.54	3.32	13.79	13.60	0.21
EPA switch cycle maximum Tier 0				2.10	8.0	14.0	14.0	0.72

APPENDIX F-6

UP No. 9733 Smoke Test Summary

SMOKE TEST SUMMARY FOR UP NO. 9733

Run #	**ss**	**30-sec**	**3-sec**
Carb Diesel (EM-2663-F)			
# 1	10	27	86
# 2	8	24	80
# 3	11	28	85
Avg	**10**	**26**	**84**
cov	16%	9%	4%
On-Highway Diesel (EM-2677-F)			
# 1	10	21	73
# 2	9	21	76
# 3	10	28	88
Avg	**10**	**23**	**79**
cov	6%	17%	10%
Nonroad High Sulfur Diesel (EM-2664-F)			
# 1	8	20	75
# 2	10	22	79
# 3	10	25	85
Avg	**9**	**22**	**80**
cov	12%	10%	6%
Fuel #4, Nonroad 0.3% Sulfur Diesel (EM-2708-F)			
# 1	9	21	80
# 2	11	24	80
# 3	11	25	85
Avg	**10**	**23**	**82**
cov	11%	8%	4%

updated 5/28/99 sgf

APPENDIX G

Benzene and 1,3 Butadiene Data

Appendix G: Benzene Emissions Summary

BNSF No. 9693

Notch	Benzene Mass Emission Rate, g/hr			Benzene Brake-Specific Emissions, mg/hp-hr			
	CARB EM-2663-F	On-Hwy EM-2677-F	High Sulfur EM-2664-F	CARB EM-2663-F	On-Hwy EM-2677-F	High Sulfur EM-2664-F	
DB-2	0.3	2.8	0.0	14.43	146.84	0.00	
Idle	0.2	0.1	0.2	15.14	5.88	11.68	
Notch 1	0.3	0.3	0.3	1.32	1.31	1.44	
Notch 2	0.4	0.5	0.3	0.81	1.04	0.72	
Notch 3	0.6	0.5	0.5	0.65	0.49	0.55	
Notch 4	0.6	0.7	0.5	0.39	0.44	0.35	
Notch 5	1.4	1.6	1.4	0.70	0.78	0.71	
Notch 6	2.6	3.0	3.3	0.90	1.05	1.14	
Notch 7	4.1	2.5	2.9	1.11	0.68	0.80	
Notch 8	4.1	3.8	3.0	0.98	0.91	0.71	
		EPA Line-Haul Duty-Cycle Composite =		**1.02**	**1.64**	**0.76**	mg/hp-hr

BNSF No. 9754

Notch	Benzene Mass Emission Rate, g/hr			Benzene Brake-Specific Emissions, mg/hp-hr			
	CARB EM-2663-F	On-Hwy EM-2677-F	High Sulfur EM-2664-F	CARB EM-2663-F	On-Hwy EM-2677-F	High Sulfur EM-2664-F	
DB-2	0.2	0.3	0.2	11.52	13.09	11.79	
Idle	0.1	0.2	0.1	10.92	13.34	6.45	
Notch 1	0.3	0.1	0.1	1.62	0.68	0.64	
Notch 2	0.3	0.0	0.0	0.78	0.00	0.03	
Notch 3	0.4	0.0	0.0	0.38	0.00	0.00	
Notch 4	0.5	0.0	0.1	0.35	0.00	0.07	
Notch 5	0.2	1.0	0.0	0.09	0.52	0.00	
Notch 6	2.5	0.5	0.4	0.87	0.18	0.14	
Notch 7	1.6	0.6	0.0	0.43	0.17	0.00	
Notch 8	1.3	0.0	0.3	0.31	0.00	0.08	
		EPA Line-Haul Duty-Cycle Composite =		**0.48**	**0.18**	**0.15**	mg/hp-hr

BNSF No. 9696 No Benzene measurements were made on BNSF No. 9696.

UP No. 9715

Notch	Benzene Mass Emission Rate, g/hr			Benzene Brake-Specific Emissions, mg/hp-hr			
	CARB EM-2663-F	On-Hwy EM-2677-F	High Sulfur EM-2664-F	CARB EM-2663-F	On-Hwy EM-2677-F	High Sulfur EM-2664-F	
DB-2	0.8	0.7	0.9	37.16	29.75	39.39	
Low Idle	0.5	0.4	0.8	51.77	37.83	81.57	
Idle	0.4	0.6	0.6	31.85	57.88	57.78	
Notch 1	0.2	0.3	0.2	1.07	1.48	1.24	
Notch 2	0.4	1.5	0.3	0.70	2.95	0.55	
Notch 3	1.4	1.2	1.2	1.32	1.13	1.20	
Notch 4	2.0	2.5	2.2	1.32	1.64	1.44	
Notch 5	3.6	4.5	5.2	1.61	2.01	2.34	
Notch 6	3.5	3.9	2.5	1.19	1.34	0.84	
Notch 7	3.3	4.7	2.6	0.90	1.28	0.71	
Notch 8	5.3	6.7	3.0	1.18	1.49	0.67	
		EPA Line-Haul Duty-Cycle Composite =		**1.42**	**1.76**	**1.19**	mg/hp-hr

UP No. 9724

Notch	Benzene Mass Emission Rate, g/hr			Benzene Brake-Specific Emissions, mg/hp-hr			
	CARB EM-2663-F	On-Hwy EM-2677-F	High Sulfur EM-2664-F	CARB EM-2663-F	On-Hwy EM-2677-F	High Sulfur EM-2664-F	
DB-2	1.3	1.2	1.5	53.84	52.39	61.08	
Low Idle	1.2	1.1	0.2	102.85	90.72	14.94	
Idle	0.7	1.0	0.8	62.46	85.94	64.68	
Notch 1	0.6	0.4	0.6	2.86	1.79	3.07	
Notch 2	1.1	0.7	1.0	2.18	1.38	2.03	
Notch 3	2.9	3.2	4.9	2.81	3.08	4.78	
Notch 4	4.8	3.6	4.2	3.13	2.35	2.69	
Notch 5	5.7	4.4	6.2	2.58	1.99	2.77	
Notch 6	5.0	3.6	5.8	1.71	1.24	1.97	
Notch 7	4.5	5.8	9.1	1.23	1.59	2.49	
Notch 8	11.6	6.7	11.8	2.57	1.49	2.62	
		EPA Line-Haul Duty-Cycle Composite =		**2.84**	**2.08**	**2.94**	mg/hp-hr

UP No. 9733 No Benzene measurements were made on UP No. 9733

File name U:\FRITZ\QPRO\08-2062_ARB LOCO\2062-BENZENE.WB3

Appendix G-2: 1,3 Butadiene Emissions Summary

BNSF No. 9693

	1,3 Butadiene Mass Emission Rate, g/hr			1,3 Butadiene Brake-Specific Emissions, mg/hp-hr			
Notch	CARB EM-2663-F	On-Hwy EM-2677-F	High Sulfur EM-2664-F	CARB EM-2663-F	On-Hwy EM-2677-F	High Sulfur EM-2664-F	
DB-2	0.4	0.5	0.2	19.28	23.39	8.00	
Idle	0.0	0.2	0.2	0.00	15.70	15.87	
Notch 1	0.0	0.3	0.2	0.00	1.25	1.12	
Notch 2	0.4	0.2	0.2	0.81	0.36	0.51	
Notch 3	0.0	0.0	0.3	0.00	0.00	0.34	
Notch 4	0.9	0.8	2.0	0.58	0.51	1.35	
Notch 5	2.9	2.8	2.9	1.43	1.41	1.43	
Notch 6	5.7	5.7	5.3	1.97	1.98	1.83	
Notch 7	5.1	6.0	7.4	1.39	1.64	2.02	
Notch 8	5.8	6.7	6.7	1.38	1.59	1.58	
		EPA Line-Haul Duty-Cycle Composite =		**1.40**	**1.60**	**1.60**	mg/hp-hr

BNSF No. 9754

	1,3 Butadiene Mass Emission Rate, g/hr			1,3 Butadiene Brake-Specific Emissions, mg/hp-hr			
Notch	CARB EM-2663-F	On-Hwy EM-2677-F	High Sulfur EM-2664-F	CARB EM-2663-F	On-Hwy EM-2677-F	High Sulfur EM-2664-F	
DB-2	0.3	0.3	0.3	13.02	13.95	14.13	
Idle	0.2	0.0	0.2	12.96	3.13	12.69	
Notch 1	0.3	0.2	0.3	1.51	1.00	1.60	
Notch 2	0.4	0.3	0.5	0.93	0.74	1.04	
Notch 3	0.4	0.7	0.5	0.39	0.73	0.46	
Notch 4	0.7	1.1	1.3	0.47	0.69	0.85	
Notch 5	1.6	2.2	2.3	0.80	1.08	1.12	
Notch 6	3.7	4.5	4.7	1.30	1.55	1.63	
Notch 7	3.5	5.2	5.1	0.95	1.43	1.40	
Notch 8	4.5	5.4	4.9	1.08	1.29	1.16	
		EPA Line-Haul Duty-Cycle Composite =		**1.10**	**1.31**	**1.28**	mg/hp-hr

BNSF No. 9696 No 1,3 Butadiene measurements were made on BNSF No. 9696.

UP No. 9715

	1,3 Butadiene Mass Emission Rate, g/hr			1,3 Butadiene Brake-Specific Emissions, mg/hp-hr			
Notch	CARB EM-2663-F	On-Hwy EM-2677-F	High Sulfur EM-2664-F	CARB EM-2663-F	On-Hwy EM-2677-F	High Sulfur EM-2664-F	
DB-2	0.9	1.4	1.3	40.80	56.73	55.39	
Low Idle	0.6	0.9	1.0	57.77	85.90	99.29	
Idle	0.6	1.0	0.7	39.86	91.61	64.25	
Notch 1	0.3	0.4	0.9	1.44	2.19	4.82	
Notch 2	0.4	0.7	0.6	0.85	1.37	1.29	
Notch 3	2.0	2.9	2.6	1.96	2.76	2.55	
Notch 4	4.5	5.6	4.4	2.90	3.59	2.83	
Notch 5	5.2	6.8	4.7	2.35	3.04	2.11	
Notch 6	5.5	1.9	6.0	1.87	0.65	2.03	
Notch 7	4.6	7.2	5.8	1.25	1.97	1.59	
Notch 8	9.3	9.7	8.6	2.08	2.17	1.93	
		EPA Line-Haul Duty-Cycle Composite =		**2.26**	**2.59**	**2.40**	mg/hp-hr

UP No. 9724

	1,3 Butadiene Mass Emission Rate, g/hr			1,3 Butadiene Brake-Specific Emissions, mg/hp-hr			
Notch	CARB EM-2663-F	On-Hwy EM-2677-F	High Sulfur EM-2664-F	CARB EM-2663-F	On-Hwy EM-2677-F	High Sulfur EM-2664-F	
DB-2	1.1	1.3	1.3	45.42	58.45	52.89	
Low Idle	1.3	1.3	0.8	105.47	112.31	70.16	
Idle	1.0	0.7	0.7	81.89	57.14	58.55	
Notch 1	0.3	0.3	0.3	1.51	1.51	1.51	
Notch 2	0.5	0.5	0.6	1.00	0.99	1.20	
Notch 3	2.1	2.4	3.3	1.98	2.34	3.17	
Notch 4	2.7	2.8	3.3	1.78	1.80	2.13	
Notch 5	2.7	3.5	3.5	1.22	1.57	1.55	
Notch 6	1.8	2.8	3.3	0.61	0.96	1.14	
Notch 7	1.8	2.9	3.7	0.49	0.79	1.02	
Notch 8	2.8	4.5	6.2	0.61	1.01	1.38	
		EPA Line-Haul Duty-Cycle Composite =		**1.25**	**1.58**	**1.81**	mg/hp-hr

UP No. 9733 No 1,3 Butadiene measurements were made on UP No. 9733

APPENDIX H

Formaldehyde, Acetaldehyde, and Acrolein Data

Appendix H-1: Formaldehyde Emissions Summary

BNSF No. 9693

	Formaldehyde Mass Emission Rate, g/hr			Formaldehyde Brake-Specific Emissions, mg/hp-hr			
Notch	CARB EM-2663-F	On-Hwy EM-2677-F	High Sulfur EM-2664-F	CARB EM-2663-F	On-Hwy EM-2677-F	High Sulfur EM-2664-F	
DB-2	8.6	14.4	8.2	443.53	745.94	426.95	
Idle	2.3	2.8	2.6	172.29	206.76	193.46	
Notch 1	3.7	2.7	3.1	18.12	12.99	15.20	
Notch 2	4.6	4.0	4.0	10.48	9.18	9.24	
Notch 3	6.8	5.4	7.2	6.89	5.48	7.30	
Notch 4	12.6	9.5	10.2	8.31	6.27	6.74	
Notch 5	21.8	21.3	20.1	10.86	10.60	9.99	
Notch 6	48.3	47.1	46.1	16.76	16.30	16.01	
Notch 7	69.5	59.6	61.4	19.01	16.33	16.80	
Notch 8	88.9	79.2	82.4	21.14	18.83	19.58	
		EPA Line-Haul Duty-Cycle Composite =		**20.72**	**20.43**	**19.27**	mg/hp-hr

BNSF No. 9754

	Formaldehyde Mass Emission Rate, g/hr			Formaldehyde Brake-Specific Emissions, mg/hp-hr			
Notch	CARB EM-2663-F	On-Hwy EM-2677-F	High Sulfur EM-2664-F	CARB EM-2663-F	On-Hwy EM-2677-F	High Sulfur EM-2664-F	
DB-2	5.2	3.0	20.8	265.22	154.07	1074.37	
Idle	2.6	1.3	5.1	190.29	93.30	375.07	
Notch 1	4.6	2.5	6.6	22.55	12.21	32.47	
Notch 2	6.4	4.8	8.9	14.68	10.98	20.24	
Notch 3	9.2	7.2	12.3	9.42	7.37	12.54	
Notch 4	23.8	5.8	16.8	15.68	3.82	11.08	
Notch 5	23.1	21.9	33.0	11.53	10.92	16.48	
Notch 6	59.5	0.3	57.8	20.61	0.09	20.06	
Notch 7	62.4	11.6	80.1	17.09	3.17	21.91	
Notch 8	97.1	78.5	93.4	23.05	18.64	22.20	
		EPA Line-Haul Duty-Cycle Composite =		**21.90**	**14.09**	**26.97**	mg/hp-hr

BNSF No. 9696 No formaldehyde measurements were made on BNSF No. 9696.

UP No. 9715

	Formaldehyde Mass Emission Rate, g/hr			Formaldehyde Brake-Specific Emissions, mg/hp-hr			
Notch	CARB EM-2663-F	On-Hwy EM-2677-F	High Sulfur EM-2664-F	CARB EM-2663-F	On-Hwy EM-2677-F	High Sulfur EM-2664-F	
DB-2	20.4	12.4	12.0	927.73	496.96	519.76	
Low Idle	18.7	8.0	8.8	1865.78	728.26	880.41	
Idle	18.1	10.9	6.7	1292.64	989.05	605.54	
Notch 1	4.9	2.7	2.5	25.38	14.89	12.77	
Notch 2	6.9	4.2	3.9	13.74	8.30	7.92	
Notch 3	22.3	17.4	19.7	21.49	16.87	19.32	
Notch 4	43.2	28.3	24.3	27.84	18.25	15.81	
Notch 5	48.3	37.3	38.7	21.75	16.77	17.42	
Notch 6	52.7	37.6	40.1	17.93	12.78	13.65	
Notch 7	58.8	43.8	42.6	16.05	11.94	11.62	
Notch 8	60.6	58.2	53.1	13.49	13.01	11.84	
		EPA Line-Haul Duty-Cycle Composite =		**23.81**	**17.69**	**16.44**	mg/hp-hr

UP No. 9724

	Formaldehyde Mass Emission Rate, g/hr			Formaldehyde Brake-Specific Emissions, mg/hp-hr			
Notch	CARB EM-2663-F	On-Hwy EM-2677-F	High Sulfur EM-2664-F	CARB EM-2663-F	On-Hwy EM-2677-F	High Sulfur EM-2664-F	
DB-2	20.2	23.2	27.0	809.32	1009.54	1080.21	
Low Idle	12.7	21.9	13.6	1058.85	1825.71	1233.51	
Idle	15.6	13.4	13.3	1299.84	1120.07	1110.83	
Notch 1	4.9	4.4	4.6	24.88	22.18	23.22	
Notch 2	9.6	9.8	7.6	19.35	19.77	15.39	
Notch 3	18.5	23.0	25.6	17.86	22.28	24.76	
Notch 4	19.0	33.4	34.9	12.26	21.55	22.53	
Notch 5	50.9	38.4	42.2	22.85	17.27	18.94	
Notch 6	43.9	37.9	44.6	14.91	12.88	15.17	
Notch 7	50.0	33.4	28.7	13.67	9.11	7.84	
Notch 8	62.1	55.5	66.6	13.79	12.36	14.80	
		EPA Line-Haul Duty-Cycle Composite =		**21.31**	**21.59**	**22.38**	mg/hp-hr

UP No. 9733 No formaldehyde measurements were made on UP No. 9733

Appendix H-2: Acetaldehyde Emissions Summary

BNSF No. 9693

	Acetaldehyde Mass Emission Rate, g/hr			Acetaldehyde Brake-Specific Emissions, mg/hp-hr			
Notch	CARB EM-2663-F	On-Hwy EM-2677-F	High Sulfur EM-2664-F	CARB EM-2663-F	On-Hwy EM-2677-F	High Sulfur EM-2664-F	
DB-2	7.1	5.6	7.7	367.46	291.35	398.37	
Idle	1.2	1.4	1.3	90.77	103.34	97.92	
Notch 1	2.1	1.5	1.7	10.40	7.26	8.37	
Notch 2	2.8	2.5	2.4	6.50	5.63	5.43	
Notch 3	4.3	2.9	3.9	4.34	2.93	3.96	
Notch 4	6.2	5.5	6.5	4.05	3.63	4.28	
Notch 5	11.2	10.0	8.2	5.56	5.00	4.06	
Notch 6	20.4	20.1	17.3	7.08	6.96	6.01	
Notch 7	30.1	27.4	24.9	8.22	7.50	6.81	
Notch 8	39.7	33.9	32.4	9.45	8.05	7.71	
		EPA Line-Haul Duty-Cycle Composite =		**10.32**	**8.85**	**9.07**	mg/hp-hr

BNSF No. 9754

	Acetaldehyde Mass Emission Rate, g/hr			Acetaldehyde Brake-Specific Emissions, mg/hp-hr			
Notch	CARB EM-2663-F	On-Hwy EM-2677-F	High Sulfur EM-2664-F	CARB EM-2663-F	On-Hwy EM-2677-F	High Sulfur EM-2664-F	
DB-2	3.4	0.9	7.9	172.58	46.15	406.62	
Idle	1.5	0.4	2.3	110.34	26.38	166.75	
Notch 1	2.6	1.0	2.9	12.69	4.76	14.40	
Notch 2	4.4	2.2	4.5	10.00	4.99	10.36	
Notch 3	6.7	3.8	6.7	6.81	3.90	6.86	
Notch 4	16.1	2.6	9.1	10.64	1.71	6.00	
Notch 5	12.5	10.5	19.6	6.21	5.23	9.77	
Notch 6	27.7	0.0	24.5	9.59	0.00	8.49	
Notch 7	32.1	6.8	36.3	8.78	1.86	9.94	
Notch 8	46.0	33.1	41.4	10.91	7.86	9.83	
		EPA Line-Haul Duty-Cycle Composite =		**11.15**	**5.95**	**11.88**	mg/hp-hr

BNSF No. 9696 No acetaldehyde measurements were made on BNSF No. 9696.

UP No. 9715

	Acetaldehyde Mass Emission Rate, g/hr			Acetaldehyde Brake-Specific Emissions, mg/hp-hr			
Notch	CARB EM-2663-F	On-Hwy EM-2677-F	High Sulfur EM-2664-F	CARB EM-2663-F	On-Hwy EM-2677-F	High Sulfur EM-2664-F	
DB-2	8.7	5.0	4.7	397.37	199.08	205.11	
Low Idle	8.3	3.4	3.7	831.19	305.29	373.33	
Idle	7.4	4.3	2.6	527.78	389.88	238.73	
Notch 1	2.6	1.1	1.1	13.47	6.42	5.76	
Notch 2	3.9	2.0	1.9	7.85	3.94	3.79	
Notch 3	10.0	6.7	7.3	9.66	6.52	7.15	
Notch 4	18.6	9.7	7.7	12.00	6.24	4.98	
Notch 5	20.0	13.4	12.7	8.99	6.04	5.69	
Notch 6	22.3	13.4	14.2	7.58	4.55	4.85	
Notch 7	24.9	16.0	16.3	6.80	4.36	4.45	
Notch 8	31.3	20.0	19.2	6.96	4.47	4.29	
		EPA Line-Haul Duty-Cycle Composite =		**10.97**	**6.47**	**6.09**	mg/hp-hr

UP No. 9724

	Acetaldehyde Mass Emission Rate, g/hr			Acetaldehyde Brake-Specific Emissions, mg/hp-hr			
Notch	CARB EM-2663-F	On-Hwy EM-2677-F	High Sulfur EM-2664-F	CARB EM-2663-F	On-Hwy EM-2677-F	High Sulfur EM-2664-F	
DB-2	8.4	8.3	10.7	334.03	360.90	426.14	
Low Idle	5.5	5.8	5.5	457.79	483.11	498.82	
Idle	6.2	5.2	5.2	520.78	437.35	432.38	
Notch 1	2.1	0.8	1.9	10.81	4.30	9.64	
Notch 2	4.1	4.5	3.1	8.17	9.07	6.26	
Notch 3	7.2	8.9	9.6	6.91	8.59	9.27	
Notch 4	7.6	12.1	12.4	4.93	7.83	7.98	
Notch 5	18.0	14.8	16.1	8.07	6.67	7.21	
Notch 6	15.7	14.6	16.2	5.34	4.97	5.50	
Notch 7	18.4	13.3	15.1	5.03	3.62	4.12	
Notch 8	22.2	19.7	26.3	4.94	4.38	5.83	
		EPA Line-Haul Duty-Cycle Composite =		**8.10**	**7.59**	**8.80**	mg/hp-hr

UP No. 9733 No acetaldehyde measurements were made on UP No. 9733

Appendix H-3: Acrolein Emissions Summary

BNSF No. 9693

Notch	Acrolein Mass Emission Rate, g/hr			Acrolein Brake-Specific Emissions, mg/hp-hr			
	CARB EM-2663-F	On-Hwy EM-2677-F	High Sulfur EM-2664-F	CARB EM-2663-F	On-Hwy EM-2677-F	High Sulfur EM-2664-F	
DB-2	0.7	0.3	0.5	35.52	13.85	28.42	
Idle	0.0	0.1	0.3	0.00	10.85	19.35	
Notch 1	0.8	0.2	0.2	3.99	1.22	0.93	
Notch 2	0.9	0.2	0.4	2.13	0.37	0.98	
Notch 3	1.4	0.3	0.8	1.46	0.26	0.84	
Notch 4	1.9	1.0	3.9	1.26	0.67	2.56	
Notch 5	2.8	2.1	4.0	1.41	1.02	2.01	
Notch 6	6.5	3.6	6.5	2.25	1.26	2.25	
Notch 7	8.4	4.2	10.2	2.28	1.15	2.79	
Notch 8	10.1	10.0	12.9	2.40	2.38	3.05	
		EPA Line-Haul Duty-Cycle Composite =		**2.38**	**1.88**	**2.85**	mg/hp-hr

BNSF No. 9754

Notch	Acrolein Mass Emission Rate, g/hr			Acrolein Brake-Specific Emissions, mg/hp-hr			
	CARB EM-2663-F	On-Hwy EM-2677-F	High Sulfur EM-2664-F	CARB EM-2663-F	On-Hwy EM-2677-F	High Sulfur EM-2664-F	
DB-2	0.1	0.1	0.4	5.68	3.85	19.52	
Idle	0.1	0.0	0.0	5.97	0.00	3.51	
Notch 1	0.3	0.0	0.2	1.57	0.00	0.74	
Notch 2	0.2	0.2	0.3	0.52	0.34	0.72	
Notch 3	0.7	0.0	0.1	0.69	0.00	0.13	
Notch 4	1.1	0.0	0.2	0.75	0.00	0.13	
Notch 5	1.4	0.2	0.7	0.69	0.11	0.34	
Notch 6	4.0	0.0	2.8	1.39	0.00	0.98	
Notch 7	3.9	0.0	3.0	1.07	0.00	0.81	
Notch 8	7.1	2.5	4.0	1.69	0.59	0.94	
		EPA Line-Haul Duty-Cycle Composite =		**1.44**	**0.39**	**0.91**	mg/hp-hr

BNSF No. 9696 No acrolein measurements were made on BNSF No. 9696.

UP No. 9715

Notch	Acrolein Mass Emission Rate, g/hr			Acrolein Brake-Specific Emissions, mg/hp-hr			
	CARB EM-2663-F	On-Hwy EM-2677-F	High Sulfur EM-2664-F	CARB EM-2663-F	On-Hwy EM-2677-F	High Sulfur EM-2664-F	
DB-2	2.1	1.2	0.7	94.49	46.04	30.62	
Low Idle	2.0	0.7	0.6	201.42	65.71	60.24	
Idle	2.2	1.0	0.5	158.49	90.16	49.49	
Notch 1	0.5	0.2	0.1	2.32	1.19	0.63	
Notch 2	0.6	0.2	0.1	1.21	0.34	0.25	
Notch 3	1.4	0.7	0.8	1.32	0.68	0.80	
Notch 4	2.8	1.1	0.9	1.83	0.74	0.58	
Notch 5	5.7	1.5	1.2	2.58	0.68	0.55	
Notch 6	5.9	1.3	1.2	2.00	0.45	0.42	
Notch 7	4.0	1.1	1.2	1.09	0.30	0.32	
Notch 8	12.9	2.0	1.8	2.88	0.44	0.41	
		EPA Line-Haul Duty-Cycle Composite =		**3.29**	**0.86**	**0.69**	mg/hp-hr

UP No. 9724

Notch	Acrolein Mass Emission Rate, g/hr			Acrolein Brake-Specific Emissions, mg/hp-hr			
	CARB EM-2663-F	On-Hwy EM-2677-F	High Sulfur EM-2664-F	CARB EM-2663-F	On-Hwy EM-2677-F	High Sulfur EM-2664-F	
DB-2	1.9	2.1	3.3	77.31	90.27	131.56	
Low Idle	1.3	2.4	1.2	111.86	198.94	111.39	
Idle	1.6	1.1	1.0	131.83	94.13	86.54	
Notch 1	0.4	0.4	0.4	2.05	2.12	2.12	
Notch 2	0.3	0.5	0.3	0.65	0.92	0.64	
Notch 3	0.3	1.0	0.9	0.31	1.00	0.90	
Notch 4	0.1	0.7	1.3	0.10	0.48	0.83	
Notch 5	1.7	0.3	1.0	0.79	0.11	0.43	
Notch 6	1.2	0.6	1.0	0.42	0.19	0.35	
Notch 7	1.2	0.0	0.0	0.34	0.00	0.00	
Notch 8	0.5	1.0	1.1	0.12	0.23	0.24	
		EPA Line-Haul Duty-Cycle Composite =		**0.91**	**1.05**	**1.03**	mg/hp-hr

UP No. 9733 No acrolein measurements were made on UP No. 9733

APPENDIX I

PAH Data

APPENDIX I-1: LOCOMOTIVE BN9693

CARB Diesel

PAH PRODUCTION , mg/hr											
COMPOUND NAME	**Notch low idle**	**Notch idle**	**Notch DB**	**Notch 1.00**	**Notch 2.00**	**Notch 3.00**	**Notch 4.00**	**Notch 5.00**	**Notch 6.00**	**Notch 7.00**	**Notch 8.00**
PARTICULATE FRACTION											
NAPHTHALENE		0.37	ND, <0.07	0.46	ND, <0.05	ND, <0.09	1.22	ND, <0.16	ND, <0.27	ND, <0.36	4.01
2-METHYLNAPHTHALENE		ND, <0.04	ND, <0.07	ND, <0.05	ND, <0.05	0.47	0.61	ND, <0.16	ND, <0.27	ND, <0.36	4.01
ACENAPHTHYLENE		ND, <0.04	ND, <0.07	ND, <0.05	ND, <0.05	ND, <0.09	ND, <0.12	ND, <0.16	TRACE	ND, <0.36	TRACE
ACENAPHTHENE		ND, <0.04	ND, <0.07	ND, <0.05	ND, <0.05	ND, <0.09	ND, <0.12	ND, <0.16	ND, <0.27	ND, <0.36	ND, <0.40
FLUORENE		ND, <0.04	ND, <0.07	ND, <0.05	TRACE	TRACE	ND, <0.12	ND, <0.16	0.93	TRACE	TRACE
PHENANTHRENE		ND, <0.04	ND, <0.07	ND, <0.05	1.44	1.33	2.80	8.32	32.68	19.14	17.25
ANTHRACENE		ND, <0.04	ND, <0.07	ND, <0.05	TRACE	TRACE	TRACE	0.78	3.59	1.99	2.01
FLUORANTHENE		0.44	0.82	1.32	2.19	2.79	5.78	9.42	14.61	14.09	15.44
PYRENE		0.65	1.45	2.26	3.34	5.21	10.34	17.26	23.91	27.09	30.08
BENZO(A)ANTHRACENE		TRACE	TRACE	0.23	0.39	0.71	0.73	0.86	0.93	1.44	1.60
CHRYSENE		0.26	0.50	0.69	1.21	2.04	2.25	3.14	3.32	4.52	5.62
BENZO(B)FLUORANTHENE		0.13	TRACE	0.30	0.36	0.66	0.67	0.94	1.06	1.26	1.60
BENZO(K)FLUORANTHENE		TRACE	TRACE	0.23	0.28	0.47	0.49	0.55	TRACE	ND, <0.36	1.40
BENZO(E)PYRENE		TRACE	TRACE	0.16	0.26	0.43	0.61	0.86	1.06	TRACE	1.81
BENZO(A)PYRENE		ND, <0.04	TRACE	TRACE	TRACE	TRACE	TRACE	0.55	TRACE	TRACE	TRACE
PERYLENE		ND, <0.04	ND, <0.07	ND, <0.05	ND, <0.05	ND, <0.09	ND, <0.12	ND, <0.16	ND, <0.27	ND, <0.36	ND, <0.40
INDENO(123-CD)PYRENE		0.13	TRACE	0.16	0.18	TRACE	TRACE	TRACE	TRACE	ND, <0.36	ND, <0.40
DIBENZ(AH)ANTHRACENE		ND, <0.04	ND, <0.07	ND, <0.05	ND, <0.05	ND, <0.09	ND, <0.12	ND, <0.16	ND, <0.27	ND, <0.36	ND, <0.40
BENZO(GHI)PERYLENE		0.13	TRACE	0.23	0.31	0.33	0.73	1.57	0.93	1.44	2.21
VAPOR FRACTION											
NAPHTHALENE		ND, <0.04	ND, <0.07	ND, <0.05	ND, <0.05	ND, <0.09	ND, <0.12	ND, <0.16	ND, <0.27	ND, <0.36	ND, <0.40
2-METHYLNAPHTHALENE		47.98	102.79	50.81	110.57	14.21	121.59	94.15	106.28	90.30	340.95
ACENAPHTHYLENE		ND, <0.04	ND, <0.07	0.46	ND, <0.05	ND, <0.09	ND, <0.12	ND, <0.16	ND, <0.27	ND, <0.36	ND, <0.40
ACENAPHTHENE		ND, <0.04	ND, <0.07	ND, <0.05	ND, <0.05	ND, <0.09	ND, <0.12	ND, <0.16	ND, <0.27	ND, <0.36	ND, <0.40
FLUORENE		2.03	3.54	6.47	9.51	3.79	4.86	ND, <0.16	ND, <0.27	ND, <0.36	6.02
PHENANTHRENE		9.96	18.79	19.86	27.26	26.05	40.12	33.74	15.94	39.73	100.28
ANTHRACENE		ND, <0.04	ND, <0.07	1.76	2.37	ND, <0.09	3.04	2.75	ND, <0.27	4.70	8.82
FLUORANTHENE		ND, <0.04	ND, <0.07	2.01	2.49	3.55	3.10	3.14	ND, <0.27	ND, <0.36	6.42
PYRENE		1.00	ND, <0.07	1.92	2.65	3.03	2.80	1.80	ND, <0.27	ND, <0.36	3.81
BENZO(A)ANTHRACENE		ND, <0.04	ND, <0.07	ND, <0.05	ND, <0.05	ND, <0.09	ND, <0.12	ND, <0.16	ND, <0.27	ND, <0.36	ND, <0.40
CHRYSENE		ND, <0.04	ND, <0.07	ND, <0.05	ND, <0.05	ND, <0.09	ND, <0.12	ND, <0.16	ND, <0.27	ND, <0.36	ND, <0.40
BENZO(B)FLUORANTHENE		ND, <0.04	ND, <0.07	ND, <0.05	ND, <0.05	ND, <0.09	ND, <0.12	ND, <0.16	ND, <0.27	ND, <0.36	ND, <0.40
BENZO(K)FLUORANTHENE		ND, <0.04	ND, <0.07	ND, <0.05	ND, <0.05	ND, <0.09	ND, <0.12	ND, <0.16	ND, <0.27	ND, <0.36	ND, <0.40
BENZO(E)PYRENE		ND, <0.04	ND, <0.07	ND, <0.05	ND, <0.05	ND, <0.09	ND, <0.12	ND, <0.16	ND, <0.27	ND, <0.36	ND, <0.40
BENZO(A)PYRENE		ND, <0.04	ND, <0.07	ND, <0.05	ND, <0.05	ND, <0.09	ND, <0.12	ND, <0.16	ND, <0.27	ND, <0.36	ND, <0.40
PERYLENE		ND, <0.04	ND, <0.07	ND, <0.05	ND, <0.05	ND, <0.09	ND, <0.12	ND, <0.16	ND, <0.27	ND, <0.36	ND, <0.40
INDENO(123-CD)PYRENE		ND, <0.04	ND, <0.07	ND, <0.05	ND, <0.05	ND, <0.09	ND, <0.12	ND, <0.16	ND, <0.27	ND, <0.36	ND, <0.40
DIBENZ(AH)ANTHRACENE		ND, <0.04	ND, <0.07	ND, <0.05	ND, <0.05	ND, <0.09	ND, <0.12	ND, <0.16	ND, <0.27	ND, <0.36	ND, <0.40
BENZO(GHI)PERYLENE		ND, <0.04	ND, <0.07	ND, <0.05	ND, <0.05	ND, <0.09	ND, <0.12	ND, <0.16	ND, <0.27	ND, <0.36	ND, <0.40

APPENDIX I-2: LOCOMOTIVE BN9693

On-Highway Diesel

PAH PRODUCTION , mg/hr											
COMPOUND NAME	**Notch low idle**	**Notch idle**	**Notch DB**	**Notch 1.00**	**Notch 2.00**	**Notch 3.00**	**Notch 4.00**	**Notch 5.00**	**Notch 6.00**	**Notch 7.00**	**Notch 8.00**
PARTICULATE FRACTION											
NAPHTHALENE		ND, <0.04	ND, <0.07	1.47	2.49	3.58	6.68	ND, <0.18	15.28	15.94	3.48
2-METHYLNAPHTHALENE		ND, <0.04	0.37	1.23	1.56	1.53	5.20	ND, <0.18	8.92	6.37	6.96
ACENAPHTHYLENE		TRACE	TRACE	TRACE	TRACE	ND, <0.10	TRACE	ND, <0.18	TRACE	TRACE	TRACE
ACENAPHTHENE		ND, <0.04	ND, <0.07	0.29	0.47	0.56	0.74	ND, <0.18	1.78	2.71	TRACE
FLUORENE		ND, <0.04	ND, <0.07	TRACE	TRACE	TRACE	TRACE	ND, <0.18	1.91	1.75	1.91
PHENANTHRENE		0.24	0.81	1.37	2.05	3.88	10.10	18.13	70.82	36.02	39.32
ANTHRACENE		ND, <0.04	ND, <0.07	TRACE	TRACE	TRACE	0.74	1.76	7.64	3.19	3.13
FLUORANTHENE		0.57	1.62	1.62	2.46	4.24	7.42	12.32	19.11	19.12	19.14
PYRENE		1.11	2.72	4.17	7.78	13.29	23.01	33.44	44.58	51.00	52.19
BENZO(A)ANTHRACENE		0.16	TRACE	0.44	0.65	0.87	0.74	1.50	1.53	2.87	2.44
CHRYSENE		0.29	0.48	0.86	1.25	1.99	2.23	3.96	5.09	5.74	7.48
BENZO(B)FLUORANTHENE		0.15	TRACE	0.34	0.44	0.61	0.82	1.23	1.40	1.91	2.61
BENZO(K)FLUORANTHENE		0.13	TRACE	0.59	0.44	0.41	0.74	0.79	1.02	TRACE	TRACE
BENZO(E)PYRENE		TRACE	TRACE	0.22	0.34	0.51	0.82	0.97	1.66	1.27	2.61
BENZO(A)PYRENE		0.18	TRACE	0.29	0.34	0.36	TRACE	0.62	1.02	TRACE	2.09
PERYLENE		ND, <0.04	ND, <0.07	ND, <0.05	ND, <0.06	ND, <0.10	ND, <0.15	ND, <0.18	ND, <0.25	ND, <0.32	ND, <0.35
INDENO(123-CD)PYRENE		0.15	TRACE	0.20	0.22	TRACE	TRACE	TRACE	ND, <0.25	ND, <0.32	ND, <0.35
DIBENZ(AH)ANTHRACENE		ND, <0.04	ND, <0.07	ND, <0.05	ND, <0.06	ND, <0.10	ND, <0.15	ND, <0.18	ND, <0.25	ND, <0.32	ND, <0.35
BENZO(GHI)PERYLENE		0.18	TRACE	0.32	0.40	0.46	0.89	1.58	1.15	1.59	2.26
VAPOR FRACTION											
NAPHTHALENE		ND, <0.04	ND, <0.07	49.02	62.25	ND, <0.10	ND, <0.15	ND, <0.18	ND, <0.25	ND, <0.32	ND, <0.35
2-METHYLNAPHTHALENE		126.09	235.07	220.59	435.78	408.85	408.30	703.97	573.17	812.76	678.45
ACENAPHTHYLENE		0.37	ND, <0.07	2.45	3.74	ND, <0.10	ND, <0.15	ND, <0.18	ND, <0.25	ND, <0.32	ND, <0.35
ACENAPHTHENE		ND, <0.04	ND, <0.07	ND, <0.05	1.87	ND, <0.10	ND, <0.15	ND, <0.18	ND, <0.25	ND, <0.32	ND, <0.35
FLUORENE		4.93	8.81	16.18	26.15	15.33	14.10	38.72	11.46	27.09	40.01
PHENANTHRENE		15.72	31.59	48.04	73.46	54.17	63.84	137.27	84.07	168.93	219.19
ANTHRACENE		1.19	ND, <0.07	3.48	5.04	ND, <0.10	ND, <0.15	9.86	ND, <0.25	13.07	16.00
FLUORANTHENE		1.52	3.09	3.60	5.20	3.68	ND, <0.15	ND, <0.18	ND, <0.25	ND, <0.32	ND, <0.35
PYRENE		1.88	3.42	5.96	9.12	6.29	6.16	5.72	ND, <0.25	ND, <0.32	11.83
BENZO(A)ANTHRACENE		ND, <0.04	ND, <0.07	ND, <0.05	ND, <0.06	ND, <0.10	ND, <0.15	ND, <0.18	ND, <0.25	ND, <0.32	ND, <0.35
CHRYSENE		ND, <0.04	ND, <0.07	ND, <0.05	ND, <0.06	ND, <0.10	ND, <0.15	ND, <0.18	ND, <0.25	ND, <0.32	ND, <0.35
BENZO(B)FLUORANTHENE		ND, <0.04	ND, <0.07	ND, <0.05	ND, <0.06	ND, <0.10	ND, <0.15	ND, <0.18	ND, <0.25	ND, <0.32	ND, <0.35
BENZO(K)FLUORANTHENE		ND, <0.04	ND, <0.07	ND, <0.05	ND, <0.06	ND, <0.10	ND, <0.15	ND, <0.18	ND, <0.25	ND, <0.32	ND, <0.35
BENZO(E)PYRENE		ND, <0.04	ND, <0.07	ND, <0.05	ND, <0.06	ND, <0.10	ND, <0.15	ND, <0.18	ND, <0.25	ND, <0.32	ND, <0.35
BENZO(A)PYRENE		ND, <0.04	ND, <0.07	ND, <0.05	ND, <0.06	ND, <0.10	ND, <0.15	ND, <0.18	ND, <0.25	ND, <0.32	ND, <0.35
PERYLENE		ND, <0.04	ND, <0.07	ND, <0.05	ND, <0.06	ND, <0.10	ND, <0.15	ND, <0.18	ND, <0.25	ND, <0.32	ND, <0.35
INDENO(123-CD)PYRENE		ND, <0.04	ND, <0.07	ND, <0.05	ND, <0.06	ND, <0.10	ND, <0.15	ND, <0.18	ND, <0.25	ND, <0.32	ND, <0.35
DIBENZ(AH)ANTHRACENE		ND, <0.04	ND, <0.07	ND, <0.05	ND, <0.06	ND, <0.10	ND, <0.15	ND, <0.18	ND, <0.25	ND, <0.32	ND, <0.35
BENZO(GHI)PERYLENE		ND, <0.04	ND, <0.07	ND, <0.05	ND, <0.06	ND, <0.10	ND, <0.15	ND, <0.18	ND, <0.25	ND, <0.32	ND, <0.35

APPENDIX I-3:LOCOMOTIVE BN9693

High-Sulfur, Nonroad Diesel

PAH PRODUCTION , mg/hr											
COMPOUND NAME	**Notch low idle**	**Notch idle**	**Notch DB**	**Notch 1.00**	**Notch 2.00**	**Notch 3.00**	**Notch 4.00**	**Notch 5.00**	**Notch 6.00**	**Notch 7.00**	**Notch 8.00**
PARTICULATE FRACTION											
NAPHTHALENE		ND, <0.04	ND, <0.06	ND, <0.05	0.29	2.76	7.46	5.43	ND, <0.23	9.84	15.18
2-METHYLNAPHTHALENE		ND, <0.04	ND, <0.06	0.51	ND, <0.06	ND, <0.11	1.49	0.90	ND, <0.23	ND, <0.33	ND, <0.00
ACENAPHTHYLENE		ND, <0.04	ND, <0.06	ND, <0.05	ND, <0.06	ND, <0.11	ND, <0.15	ND, <0.18	ND, <0.23	ND, <0.33	ND, <0.00
ACENAPHTHENE		ND, <0.04	ND, <0.06	0.31	ND, <0.06	ND, <0.11	ND, <0.15	ND, <0.18	ND, <0.23	ND, <0.33	ND, <0.00
FLUORENE		ND, <0.04	ND, <0.06	0.20	ND, <0.06	ND, <0.11	ND, <0.15	ND, <0.18	TRACE	ND, <0.33	0.95
PHENANTHRENE		0.32	0.25	0.92	0.90	1.49	4.18	8.68	26.54	17.39	22.00
ANTHRACENE		ND, <0.04	ND, <0.06	TRACE	TRACE	TRACE	TRACE	0.72	1.88	1.80	1.90
FLUORANTHENE		0.61	0.78	1.53	2.27	3.26	7.16	10.85	15.27	13.78	15.36
PYRENE		0.80	1.41	2.00	2.38	5.41	8.95	12.66	19.97	22.97	30.35
BENZO(A)ANTHRACENE		0.15	TRACE	0.28	0.35	1.05	1.27	1.18	1.64	2.13	2.47
CHRYSENE		0.34	0.53	0.84	1.77	3.37	3.58	4.16	6.11	6.73	7.59
BENZO(B)FLUORANTHENE		0.17	TRACE	0.28	0.35	0.88	0.67	1.09	1.17	1.64	2.66
BENZO(K)FLUORANTHENE		0.15	0.22	0.23	0.35	0.72	0.52	0.72	0.82	1.31	0.95
BENZO(E)PYRENE		TRACE	TRACE	TRACE	TRACE	0.44	0.52	0.81	1.06	1.64	2.28
BENZO(A)PYRENE		ND, <0.04	TRACE	TRACE	TRACE	TRACE	TRACE	0.72	0.82	1.31	2.09
PERYLENE		ND, <0.04	ND, <0.06	ND, <0.05	ND, <0.06	ND, <0.11	ND, <0.15	ND, <0.18	ND, <0.23	ND, <0.33	ND, <0.00
INDENO(123-CD)PYRENE		TRACE	TRACE	TRACE	TRACE	TRACE	TRACE	TRACE	ND, <0.23	ND, <0.33	0.38
DIBENZ(AH)ANTHRACENE		ND, <0.04	ND, <0.06	ND, <0.05	ND, <0.06	ND, <0.11	ND, <0.15	ND, <0.18	ND, <0.23	ND, <0.33	ND, <0.00
BENZO(GHI)PERYLENE		TRACE	0.22	TRACE	0.20	TRACE	0.60	1.18	1.64	1.97	2.85
VAPOR FRACTION											
NAPHTHALENE		ND, <0.04	ND, <0.06	ND, <0.05	ND, <0.06	55.19	596.91	ND, <0.18	ND, <0.23	ND, <0.33	ND, <0.38
2-METHYLNAPHTHALENE		124.27	191.48	171.39	290.49	259.41	596.91	153.72	246.64	278.88	303.50
ACENAPHTHYLENE		1.68	0.94	ND, <0.05	0.87	ND, <0.11	12.68	ND, <0.18	ND, <0.23	ND, <0.33	ND, <0.38
ACENAPHTHENE		ND, <0.04	ND, <0.06	ND, <0.05	ND, <0.06	ND, <0.11	ND, <0.15	ND, <0.18	ND, <0.23	ND, <0.33	ND, <0.38
FLUORENE		9.48	15.70	13.30	24.40	33.67	48.50	9.04	15.27	11.48	20.87
PHENANTHRENE		24.43	39.55	37.35	68.56	108.18	161.17	58.78	101.00	108.27	125.20
ANTHRACENE		1.52	2.57	2.00	3.25	7.29	11.34	4.07	6.58	10.66	12.33
FLUORANTHENE		2.04	2.35	2.99	5.72	8.11	7.98	3.07	4.35	5.09	ND, <0.38
PYRENE		2.17	3.23	2.63	3.57	7.34	5.45	ND, <0.18	1.64	ND, <0.33	ND, <0.38
BENZO(A)ANTHRACENE		ND, <0.04	ND, <0.06	ND, <0.05	ND, <0.06	ND, <0.11	ND, <0.15	ND, <0.18	ND, <0.23	ND, <0.33	ND, <0.38
CHRYSENE		ND, <0.04	ND, <0.06	ND, <0.05	ND, <0.06	ND, <0.11	ND, <0.15	ND, <0.18	ND, <0.23	ND, <0.33	ND, <0.38
BENZO(B)FLUORANTHENE		ND, <0.04	ND, <0.06	ND, <0.05	ND, <0.06	ND, <0.11	ND, <0.15	ND, <0.18	ND, <0.23	ND, <0.33	ND, <0.38
BENZO(K)FLUORANTHENE		ND, <0.04	ND, <0.06	ND, <0.05	ND, <0.06	ND, <0.11	ND, <0.15	ND, <0.18	ND, <0.23	ND, <0.33	ND, <0.38
BENZO(E)PYRENE		ND, <0.04	ND, <0.06	ND, <0.05	ND, <0.06	ND, <0.11	ND, <0.15	ND, <0.18	ND, <0.23	ND, <0.33	ND, <0.38
BENZO(A)PYRENE		ND, <0.04	ND, <0.06	ND, <0.05	ND, <0.06	ND, <0.11	ND, <0.15	ND, <0.18	ND, <0.23	ND, <0.33	ND, <0.38
PERYLENE		ND, <0.04	ND, <0.06	ND, <0.05	ND, <0.06	ND, <0.11	ND, <0.15	ND, <0.18	ND, <0.23	ND, <0.33	ND, <0.38
INDENO(123-CD)PYRENE		ND, <0.04	ND, <0.06	ND, <0.05	ND, <0.06	ND, <0.11	ND, <0.15	ND, <0.18	ND, <0.23	ND, <0.33	ND, <0.38
DIBENZ(AH)ANTHRACENE		ND, <0.04	ND, <0.06	ND, <0.05	ND, <0.06	ND, <0.11	ND, <0.15	ND, <0.18	ND, <0.23	ND, <0.33	ND, <0.38
BENZO(GHI)PERYLENE		ND, <0.04	ND, <0.06	ND, <0.05	ND, <0.06	ND, <0.11	ND, <0.15	ND, <0.18	ND, <0.23	ND, <0.33	ND, <0.38

APPENDIX I-4: LOCOMOTIVE BN9754

CARB Diesel

PAH PRODUCTION , mg/hr										
COMPOUND NAME	**Notch idle**	**Notch DB**	**Notch 1.00**	**Notch 2.00**	**Notch 3.00**	**Notch 4.00**	**Notch 5.00**	**Notch 6.00**	**Notch 7.00**	**Notch 8.00**
PARTICULATE FRACTION										
NAPHTHALENE	0.95	3.48	2.12	4.08	8.10	3.89	10.52	185.31	27.11	18.53
2-METHYLNAPHTHALENE	0.56	1.55	1.54	2.25	3.02	1.95	5.79	11.94	11.79	9.55
ACENAPHTHYLENE	ND, <0.03	ND, <0.05	ND, <0.04	ND, <0.06	ND, <0.09	ND, <0.13	ND, <0.15	ND, <0.22	ND, <0.27	ND, <0.29
ACENAPHTHENE	0.15	0.58	0.46	0.58	1.13	0.52	1.73	2.90	3.66	3.28
FLUORENE	TRACE	0.19	0.18	0.20	0.36	TRACE	ND, <0.15	0.89	1.36	1.57
PHENANTHRENE	0.45	1.09	1.17	1.78	3.42	3.50	6.09	13.51	13.69	14.40
ANTHRACENE	ND, <0.03	ND, <0.05	TRACE	TRACE	TRACE	TRACE	TRACE	1.34	TRACE	TRACE
FLUORANTHENE	0.37	0.65	1.01	1.66	2.66	2.72	5.34	7.26	6.64	9.41
PYRENE	0.68	1.39	2.47	4.38	6.75	7.78	12.02	23.44	23.05	21.38
BENZO(A)ANTHRACENE	0.14	0.19	0.41	0.55	0.86	0.78	0.83	1.56	1.90	1.85
CHRYSENE	0.23	0.42	0.67	0.96	1.80	1.82	2.40	4.13	4.61	4.42
BENZO(B)FLUORANTHENE	0.15	0.19	0.37	0.47	0.99	0.97	1.20	1.56	1.63	1.85
BENZO(K)FLUORANTHENE	0.15	0.19	0.32	0.41	0.45	0.52	0.53	TRACE	1.08	TRACE
BENZO(E)PYRENE	0.11	TRACE	0.28	0.41	1.22	0.78	0.90	1.34	1.49	1.57
BENZO(A)PYRENE	0.18	0.23	0.37	0.41	0.54	0.45	0.60	0.78	1.22	1.14
PERYLENE	ND, <0.03	ND, <0.05	ND, <0.04	ND, <0.06	ND, <0.09	ND, <0.13	ND, <0.15	ND, <0.22	ND, <0.27	ND, <0.29
INDENO(123-CD)PYRENE	0.12	0.16	0.18	TRACE	TRACE	TRACE	TRACE	TRACE	ND, <0.27	ND, <0.29
DIBENZ(AH)ANTHRACENE	ND, <0.03	ND, <0.05	ND, <0.04	ND, <0.06	ND, <0.09	TRACE	0.53	TRACE	TRACE	ND, <0.29
BENZO(GHI)PERYLENE	0.16	0.26	0.30	0.41	0.59	0.71	0.83	1.45	1.22	1.43
VAPOR FRACTION										
NAPHTHALENE	6.80	20.87	24.75	ND, <0.06	ND, <0.09	ND, <0.13	593.70	ND, <0.22	ND, <0.27	ND, <0.29
2-METHYLNAPHTHALENE	95.16	125.23	95.45	151.67	202.56	265.88	345.70	435.38	732.07	727.07
ACENAPHTHYLENE	8.43	8.81	12.37	11.67	12.15	12.32	18.79	23.44	28.47	24.24
ACENAPHTHENE	0.82	0.70	1.24	0.88	0.90	ND, <0.13	ND, <0.15	ND, <0.22	ND, <0.27	ND, <0.29
FLUORENE	7.37	11.87	8.52	9.68	13.59	14.40	24.95	22.55	38.23	43.05
PHENANTHRENE	17.13	17.62	20.50	25.08	38.71	37.61	64.63	66.98	116.59	136.86
ANTHRACENE	1.90	2.16	2.30	3.21	4.50	4.47	6.69	8.04	12.34	12.69
FLUORANTHENE	1.32	1.62	1.77	2.71	4.01	3.89	5.11	ND, <0.22	8.41	8.70
PYRENE	2.04	2.55	2.83	3.79	5.85	5.58	7.06	5.81	11.66	12.26
BENZO(A)ANTHRACENE	ND, <0.03	ND, <0.05	ND, <0.04	ND, <0.06	ND, <0.09	ND, <0.13	ND, <0.15	ND, <0.22	ND, <0.27	ND, <0.29
CHRYSENE	ND, <0.03	ND, <0.05	ND, <0.04	ND, <0.06	ND, <0.09	ND, <0.13	ND, <0.15	ND, <0.22	ND, <0.27	ND, <0.29
BENZO(B)FLUORANTHENE	ND, <0.03	ND, <0.05	ND, <0.04	ND, <0.06	ND, <0.09	ND, <0.13	ND, <0.15	ND, <0.22	ND, <0.27	ND, <0.29
BENZO(K)FLUORANTHENE	ND, <0.03	ND, <0.05	ND, <0.04	ND, <0.06	ND, <0.09	ND, <0.13	ND, <0.15	ND, <0.22	ND, <0.27	ND, <0.29
BENZO(E)PYRENE	ND, <0.03	ND, <0.05	ND, <0.04	ND, <0.06	ND, <0.09	ND, <0.13	ND, <0.15	ND, <0.22	ND, <0.27	ND, <0.29
BENZO(A)PYRENE	ND, <0.03	ND, <0.05	ND, <0.04	ND, <0.06	ND, <0.09	ND, <0.13	ND, <0.15	ND, <0.22	ND, <0.27	ND, <0.29
PERYLENE	ND, <0.03	ND, <0.05	ND, <0.04	ND, <0.06	ND, <0.09	ND, <0.13	ND, <0.15	ND, <0.22	ND, <0.27	ND, <0.29
INDENO(123-CD)PYRENE	ND, <0.03	ND, <0.05	ND, <0.04	ND, <0.06	ND, <0.09	ND, <0.13	ND, <0.15	ND, <0.22	ND, <0.27	ND, <0.29
DIBENZ(AH)ANTHRACENE	ND, <0.03	ND, <0.05	ND, <0.04	ND, <0.06	ND, <0.09	ND, <0.13	ND, <0.15	ND, <0.22	ND, <0.27	ND, <0.29
BENZO(GHI)PERYLENE	ND, <0.03	ND, <0.05	ND, <0.04	ND, <0.06	ND, <0.09	ND, <0.13	ND, <0.15	ND, <0.22	ND, <0.27	ND, <0.29

APPENDIX I-5: LOCOMOTIVE BN9754

On-Highway Diesel

PAH PRODUCTION , mg/hr										
COMPOUND NAME	**Notch idle**	**Notch DB**	**Notch 1.00**	**Notch 2.00**	**Notch 3.00**	**Notch 4.00**	**Notch 5.00**	**Notch 6.00**	**Notch 7.00**	**Notch 8.00**
PARTICULATE FRACTION										
NAPHTHALENE	1.07	1.19	0.99	2.33	6.18	7.54	4.75	10.87	8.67	9.87
2-METHYLNAPHTHALENE	0.67	0.74	0.63	0.85	1.75	4.59	2.95	8.09	5.06	5.92
ACENAPHTHYLENE	ND, <0.03	ND, <0.06	ND, <0.04	ND, <0.05	ND, <0.10	ND, <0.14	ND, <0.19	ND, <0.24	ND, <0.29	ND, <0.33
ACENAPHTHENE	0.28	0.42	0.22	0.47	1.03	1.44	1.43	2.17	1.30	1.64
FLUORENE	TRACE	TRACE	TRACE	0.21	0.41	0.55	ND, <0.19	1.21	1.01	TRACE
PHENANTHRENE	0.75	1.25	1.23	2.61	5.20	7.60	12.45	24.27	29.05	21.55
ANTHRACENE	TRACE	ND, <0.06	TRACE	TRACE	TRACE	TRACE	TRACE	1.69	1.59	TRACE
FLUORANTHENE	0.48	0.86	1.17	2.04	2.89	3.97	5.89	9.66	14.45	9.21
PYRENE	1.12	2.62	3.76	7.24	13.39	17.81	27.57	42.25	50.58	37.83
BENZO(A)ANTHRACENE	0.18	0.21	0.36	1.03	1.55	1.23	1.24	1.69	2.60	1.81
CHRYSENE	0.34	0.51	0.47	1.50	2.68	2.60	3.04	6.76	6.36	6.09
BENZO(B)FLUORANTHENE	0.20	0.24	0.45	0.78	1.13	1.30	1.33	1.33	1.73	1.81
BENZO(K)FLUORANTHENE	0.21	0.21	0.30	0.44	TRACE	0.48	TRACE	0.85	1.01	1.15
BENZO(E)PYRENE	0.12	TRACE	0.38	0.44	1.91	1.37	0.76	1.33	1.45	1.64
BENZO(A)PYRENE	0.23	0.30	0.44	0.47	0.88	0.48	TRACE	0.85	1.01	TRACE
PERYLENE	ND, <0.03	ND, <0.06	ND, <0.04	ND, <0.05	ND, <0.10	ND, <0.14	ND, <0.19	ND, <0.24	ND, <0.29	ND, <0.33
INDENO(123-CD)PYRENE	0.18	TRACE	ND, <0.04	0.26	TRACE	TRACE	ND, <0.19	ND, <0.24	TRACE	1.48
DIBENZ(AH)ANTHRACENE	ND, <0.03	ND, <0.06	ND, <0.04	ND, <0.05	ND, <0.10	ND, <0.14	ND, <0.19	ND, <0.24	TRACE	ND, <0.33
BENZO(GHI)PERYLENE	0.25	0.27	0.34	0.44	0.62	0.89	1.33	1.69	2.17	1.81
VAPOR FRACTION										
NAPHTHALENE	44.46	74.46	27.69	90.51	118.49	ND, <0.14	ND, <0.19	60.36	28.90	ND, <0.33
2-METHYLNAPHTHALENE	167.12	294.88	215.57	359.45	870.67	609.72	827.12	1074.43	997.19	1118.57
ACENAPHTHYLENE	9.51	13.40	11.27	13.96	22.67	19.87	23.77	36.22	39.02	32.90
ACENAPHTHENE	2.76	4.77	4.15	8.79	17.00	ND, <0.14	ND, <0.19	ND, <0.24	ND, <0.29	ND, <0.33
FLUORENE	13.83	23.29	21.79	36.26	61.93	56.31	46.77	59.40	85.56	77.64
PHENANTHRENE	33.12	52.42	50.63	94.65	167.95	147.98	148.31	212.47	268.81	256.61
ANTHRACENE	2.76	3.87	3.96	6.21	10.82	9.59	10.46	15.69	18.79	18.09
FLUORANTHENE	1.69	1.94	2.77	4.40	7.21	6.17	5.04	6.76	8.38	9.05
PYRENE	2.91	3.87	4.94	9.57	17.00	13.70	10.46	13.28	17.34	19.74
BENZO(A)ANTHRACENE	ND, <0.03	ND, <0.06	ND, <0.04	ND, <0.05	ND, <0.10	ND, <0.14	ND, <0.19	ND, <0.24	ND, <0.29	ND, <0.33
CHRYSENE	ND, <0.03	ND, <0.06	ND, <0.04	ND, <0.05	ND, <0.10	ND, <0.14	ND, <0.19	ND, <0.24	ND, <0.29	ND, <0.33
BENZO(B)FLUORANTHENE	ND, <0.03	ND, <0.06	ND, <0.04	ND, <0.05	ND, <0.10	ND, <0.14	ND, <0.19	ND, <0.24	ND, <0.29	ND, <0.33
BENZO(K)FLUORANTHENE	ND, <0.03	ND, <0.06	ND, <0.04	ND, <0.05	ND, <0.10	ND, <0.14	ND, <0.19	ND, <0.24	ND, <0.29	ND, <0.33
BENZO(E)PYRENE	ND, <0.03	ND, <0.06	ND, <0.04	ND, <0.05	ND, <0.10	ND, <0.14	ND, <0.19	ND, <0.24	ND, <0.29	ND, <0.33
BENZO(A)PYRENE	ND, <0.03	ND, <0.06	ND, <0.04	ND, <0.05	ND, <0.10	ND, <0.14	ND, <0.19	ND, <0.24	ND, <0.29	ND, <0.33
PERYLENE	ND, <0.03	ND, <0.06	ND, <0.04	ND, <0.05	ND, <0.10	ND, <0.14	ND, <0.19	ND, <0.24	ND, <0.29	ND, <0.33
INDENO(123-CD)PYRENE	ND, <0.03	ND, <0.06	ND, <0.04	ND, <0.05	ND, <0.10	ND, <0.14	ND, <0.19	ND, <0.24	ND, <0.29	ND, <0.33
DIBENZ(AH)ANTHRACENE	ND, <0.03	ND, <0.06	ND, <0.04	ND, <0.05	ND, <0.10	ND, <0.14	ND, <0.19	ND, <0.24	ND, <0.29	ND, <0.33
BENZO(GHI)PERYLENE	ND, <0.03	ND, <0.06	ND, <0.04	ND, <0.05	ND, <0.10	ND, <0.14	ND, <0.19	ND, <0.24	ND, <0.29	ND, <0.33

APPENDIX I-6: LOCOMOTIVE BN9754

High-Sulfur, Nonroad Diesel

PAH PRODUCTION , mg/hr										
COMPOUND NAME	**Notch idle**	**Notch DB**	**Notch 1.00**	**Notch 2.00**	**Notch 3.00**	**Notch 4.00**	**Notch 5.00**	**Notch 6.00**	**Notch 7.00**	**Notch 8.00**
PARTICULATE FRACTION										
NAPHTHALENE	0.92	2.63	2.17	ND, <0.06	ND, <0.10	ND, <0.13	0.95	ND, <0.23	14.88	24.84
2-METHYLNAPHTHALENE	0.22	0.96	0.85	0.52	ND, <0.10	1.89	1.05	ND, <0.23	5.12	7.63
ACENAPHTHYLENE	ND, <0.04	ND, <0.06	ND, <0.04	ND, <0.06	ND, <0.10	ND, <0.13	ND, <0.19	ND, <0.23	ND, <0.33	ND, <0.00
ACENAPHTHENE	ND, <0.04	0.26	0.24	0.31	ND, <0.10	0.74	TRACE	TRACE	1.49	1.95
FLUORENE	TRACE	TRACE	TRACE	TRACE	TRACE	TRACE	ND, <0.19	TRACE	TRACE	0.89
PHENANTHRENE	0.57	1.26	1.42	2.31	4.55	8.83	9.63	16.17	20.00	17.92
ANTHRACENE	ND, <0.04	ND, <0.06	TRACE	TRACE	TRACE	TRACE	0.67	1.15	1.32	0.71
FLUORANTHENE	0.57	0.93	1.48	2.41	4.05	6.20	9.53	9.86	10.25	7.81
PYRENE	0.90	1.90	2.37	4.01	10.49	14.15	15.25	20.64	23.14	24.84
BENZO(A)ANTHRACENE	0.15	0.29	0.40	0.65	1.20	1.48	1.43	2.29	2.98	2.66
CHRYSENE	0.41	0.64	1.11	1.97	3.80	3.97	4.58	6.42	7.27	7.10
BENZO(B)FLUORANTHENE	0.26	0.29	0.45	0.77	1.15	1.08	1.43	1.95	2.31	2.13
BENZO(K)FLUORANTHENE	0.18	0.23	0.24	0.28	0.50	0.61	0.67	1.03	1.32	0.71
BENZO(E)PYRENE	TRACE	TRACE	0.20	0.31	0.75	0.94	0.86	1.61	1.82	1.95
BENZO(A)PYRENE	ND, <0.04	ND, <0.06	TRACE	TRACE	0.35	0.47	0.67	1.26	TRACE	0.89
PERYLENE	ND, <0.04	ND, <0.06	ND, <0.04	ND, <0.06	ND, <0.10	ND, <0.13	ND, <0.19	ND, <0.23	ND, <0.33	ND, <0.00
INDENO(123-CD)PYRENE	TRACE	TRACE	0.14	TRACE	TRACE	TRACE	TRACE	ND, <0.23	ND, <0.33	ND, <0.00
DIBENZ(AH)ANTHRACENE	ND, <0.04	ND, <0.06	ND, <0.04	ND, <0.06	ND, <0.10	ND, <0.13	ND, <0.19	ND, <0.23	ND, <0.33	ND, <0.00
BENZO(GHI)PERYLENE	TRACE	TRACE	0.16	0.31	0.35	0.54	1.05	1.15	1.82	1.77
VAPOR FRACTION										
NAPHTHALENE	ND, <0.04	ND, <0.06	ND, <0.04	ND, <0.06	ND, <0.10	ND, <0.13	ND, <0.19	ND, <0.23	ND, <0.33	ND, <0.35
2-METHYLNAPHTHALENE	73.81	219.04	164.03	218.94	319.78	282.96	285.99	389.83	562.09	603.24
ACENAPHTHYLENE	8.49	12.27	11.46	12.03	15.99	20.21	22.88	37.84	34.72	33.71
ACENAPHTHENE	1.66	3.50	3.56	4.63	6.50	ND, <0.13	ND, <0.19	ND, <0.23	ND, <0.33	ND, <0.35
FLUORENE	9.45	18.46	16.25	22.57	32.58	35.17	30.70	42.65	43.31	50.03
PHENANTHRENE	21.40	39.72	40.71	54.27	82.94	98.36	81.99	121.54	125.64	152.59
ANTHRACENE	1.70	3.21	2.96	4.01	6.50	8.08	7.63	11.12	13.06	14.90
FLUORANTHENE	1.33	2.07	2.37	2.99	4.75	4.51	5.24	6.31	ND, <0.33	9.23
PYRENE	1.57	2.92	2.17	2.84	5.00	5.05	ND, <0.19	ND, <0.23	ND, <0.33	8.87
BENZO(A)ANTHRACENE	ND, <0.04	ND, <0.06	ND, <0.04	ND, <0.06	ND, <0.10	ND, <0.13	ND, <0.19	ND, <0.23	ND, <0.33	ND, <0.35
CHRYSENE	ND, <0.04	ND, <0.06	ND, <0.04	ND, <0.06	ND, <0.10	ND, <0.13	ND, <0.19	ND, <0.23	ND, <0.33	ND, <0.35
BENZO(B)FLUORANTHENE	ND, <0.04	ND, <0.06	ND, <0.04	ND, <0.06	ND, <0.10	ND, <0.13	ND, <0.19	ND, <0.23	ND, <0.33	ND, <0.35
BENZO(K)FLUORANTHENE	ND, <0.04	ND, <0.06	ND, <0.04	ND, <0.06	ND, <0.10	ND, <0.13	ND, <0.19	ND, <0.23	ND, <0.33	ND, <0.35
BENZO(E)PYRENE	ND, <0.04	ND, <0.06	ND, <0.04	ND, <0.06	ND, <0.10	ND, <0.13	ND, <0.19	ND, <0.23	ND, <0.33	ND, <0.35
BENZO(A)PYRENE	ND, <0.04	ND, <0.06	ND, <0.04	ND, <0.06	ND, <0.10	ND, <0.13	ND, <0.19	ND, <0.23	ND, <0.33	ND, <0.35
PERYLENE	ND, <0.04	ND, <0.06	ND, <0.04	ND, <0.06	ND, <0.10	ND, <0.13	ND, <0.19	ND, <0.23	ND, <0.33	ND, <0.35
INDENO(123-CD)PYRENE	ND, <0.04	ND, <0.06	ND, <0.04	ND, <0.06	ND, <0.10	ND, <0.13	ND, <0.19	ND, <0.23	ND, <0.33	ND, <0.35
DIBENZ(AH)ANTHRACENE	ND, <0.04	ND, <0.06	ND, <0.04	ND, <0.06	ND, <0.10	ND, <0.13	ND, <0.19	ND, <0.23	ND, <0.33	ND, <0.35
BENZO(GHI)PERYLENE	ND, <0.04	ND, <0.06	ND, <0.04	ND, <0.06	ND, <0.10	ND, <0.13	ND, <0.19	ND, <0.23	ND, <0.33	ND, <0.35

APPENDIX I-7: LOCOMOTIVE UP9715
CARB Diesel

PAH PRODUCTION , mg/hr											
COMPOUND NAME	**Notch low idle**	**Notch idle**	**Notch DB**	**Notch 1.00**	**Notch 2.00**	**Notch 3.00**	**Notch 4.00**	**Notch 5.00**	**Notch 6.00**	**Notch 7.00**	**Notch 8.00**
PARTICULATE FRACTION											
NAPHTHALENE	0.69	0.12	1.09	0.54	88.05	4.52	2.99	8.77	5.39	11.85	13.09
2-METHYLNAPHTHALENE	ND, <0.01	ND, <0.02	ND, <0.02	ND, <0.02	24.14	ND, <0.08	ND, <0.13	ND, <0.21	ND, <0.24	ND, <0.32	ND, <0.35
ACENAPHTHYLENE	TRACE	TRACE	TRACE	ND, <0.02	0.23	ND, <0.08	ND, <0.13	ND, <0.21	TRACE	TRACE	TRACE
ACENAPHTHENE	ND, <0.01	ND, <0.02	ND, <0.02	ND, <0.02	ND, <0.03	ND, <0.08	ND, <0.13	ND, <0.21	ND, <0.24	ND, <0.32	ND, <0.35
FLUORENE	ND, <0.01	ND, <0.02	ND, <0.02	ND, <0.02	ND, <0.03	ND, <0.08	ND, <0.13	ND, <0.21	ND, <0.24	ND, <0.32	ND, <0.35
PHENANTHRENE	ND, <0.01	ND, <0.02	ND, <0.02	ND, <0.02	ND, <0.03	0.96	2.30	9.77	12.59	19.73	51.62
ANTHRACENE	0.07	TRACE	TRACE	TRACE	0.13	0.35	0.54	1.86	2.53	3.49	6.66
FLUORANTHENE	1.02	1.04	1.27	1.08	1.61	10.24	20.74	37.29	39.82	38.09	38.58
PYRENE	2.03	2.08	2.42	2.16	3.39	17.33	28.10	48.68	51.88	52.37	47.35
BENZO(A)ANTHRACENE	0.87	0.76	0.97	1.00	1.13	3.66	2.34	4.97	4.71	3.33	2.81
CHRYSENE	1.24	1.20	1.50	1.91	2.58	7.49	4.95	9.22	9.17	7.62	6.14
BENZO(B)FLUORANTHENE	0.53	0.62	0.68	1.58	2.42	5.12	2.61	5.18	4.83	3.49	2.63
BENZO(K)FLUORANTHENE	1.02	0.75	0.81	1.25	1.94	3.70	1.81	4.25	3.50	2.54	2.63
BENZO(E)PYRENE	0.54	0.69	0.75	1.16	3.23	3.94	1.87	3.42	3.38	2.54	2.10
BENZO(A)PYRENE	0.87	0.77	0.98	0.48	0.42	2.44	1.47	4.14	3.74	2.70	2.81
PERYLENE	0.11	0.06	0.08	ND, <0.02	ND, <0.03	ND, <0.08	ND, <0.13	TRACE	TRACE	ND, <0.32	ND, <0.35
INDENO(123-CD)PYRENE	0.80	0.66	0.82	0.75	0.84	2.17	1.27	3.00	2.41	1.90	1.40
DIBENZ(AH)ANTHRACENE	0.09	0.06	TRACE	0.07	TRACE	0.28	TRACE	TRACE	TRACE	ND, <0.32	ND, <0.35
BENZO(GHI)PERYLENE	1.02	0.80	1.11	0.82	0.56	2.88	1.74	4.04	3.62	2.86	2.46
VAPOR FRACTION											
NAPHTHALENE	337.20	346.98	557.89	144.80	147.00	725.14	897.03	1181.53	1617.60	2286.34	1824.98
2-METHYLNAPHTHALENE	84.82	93.31	146.06	97.11	107.72	420.48	426.43	608.37	865.51	503.61	398.67
ACENAPHTHYLENE	35.11	29.83	66.06	18.57	23.11	103.69	52.99	72.71	76.25	65.38	52.96
ACENAPHTHENE	2.68	2.07	4.71	1.15	0.94	3.09	ND, <0.13	ND, <0.21	ND, <0.24	ND, <0.32	ND, <0.35
FLUORENE	17.56	15.32	26.70	9.29	7.04	23.10	9.79	7.91	16.45	15.29	8.13
PHENANTHRENE	41.93	38.94	63.05	27.21	26.97	101.29	85.04	90.22	129.22	135.05	84.35
ANTHRACENE	5.20	4.36	6.86	2.87	2.18	10.05	5.69	4.66	6.64	ND, <0.32	ND, <0.35
FLUORANTHENE	7.47	7.42	11.86	4.48	3.85	15.71	7.94	6.08	8.29	10.90	ND, <0.35
PYRENE	9.67	9.84	13.03	6.00	4.86	15.01	7.43	4.25	6.15	8.09	ND, <0.35
BENZO(A)ANTHRACENE	ND, <0.01	ND, <0.02	ND, <0.02	ND, <0.02	ND, <0.03	ND, <0.08	ND, <0.13	ND, <0.21	ND, <0.24	ND, <0.32	ND, <0.35
CHRYSENE	ND, <0.01	ND, <0.02	ND, <0.02	ND, <0.02	ND, <0.03	ND, <0.08	ND, <0.13	ND, <0.21	ND, <0.24	ND, <0.32	ND, <0.35
BENZO(B)FLUORANTHENE	ND, <0.01	ND, <0.02	ND, <0.02	ND, <0.02	ND, <0.03	ND, <0.08	ND, <0.13	ND, <0.21	ND, <0.24	ND, <0.32	ND, <0.35
BENZO(K)FLUORANTHENE	ND, <0.01	ND, <0.02	ND, <0.02	ND, <0.02	ND, <0.03	ND, <0.08	ND, <0.13	ND, <0.21	ND, <0.24	ND, <0.32	ND, <0.35
BENZO(E)PYRENE	ND, <0.01	ND, <0.02	ND, <0.02	ND, <0.02	ND, <0.03	ND, <0.08	ND, <0.13	ND, <0.21	ND, <0.24	ND, <0.32	ND, <0.35
BENZO(A)PYRENE	ND, <0.01	ND, <0.02	ND, <0.02	ND, <0.02	ND, <0.03	ND, <0.08	ND, <0.13	ND, <0.21	ND, <0.24	ND, <0.32	ND, <0.35
PERYLENE	ND, <0.01	ND, <0.02	ND, <0.02	ND, <0.02	ND, <0.03	ND, <0.08	ND, <0.13	ND, <0.21	ND, <0.24	ND, <0.32	ND, <0.35
INDENO(123-CD)PYRENE	ND, <0.01	ND, <0.02	ND, <0.02	ND, <0.02	ND, <0.03	ND, <0.08	ND, <0.13	ND, <0.21	ND, <0.24	ND, <0.32	ND, <0.35
DIBENZ(AH)ANTHRACENE	ND, <0.01	ND, <0.02	ND, <0.02	ND, <0.02	ND, <0.03	ND, <0.08	ND, <0.13	ND, <0.21	ND, <0.24	ND, <0.32	ND, <0.35
BENZO(GHI)PERYLENE	ND, <0.01	ND, <0.02	ND, <0.02	ND, <0.02	ND, <0.03	ND, <0.08	ND, <0.13	ND, <0.21	ND, <0.24	ND, <0.32	ND, <0.35

APPENDIX I-8: LOCOMOTIVE UP9715

On-Highway Diesel

PAH PRODUCTION , mg/hr											
COMPOUND NAME	**Notch low idle**	**Notch idle**	**Notch DB**	**Notch 1.00**	**Notch 2.00**	**Notch 3.00**	**Notch 4.00**	**Notch 5.00**	**Notch 6.00**	**Notch 7.00**	**Notch 8.00**
PARTICULATE FRACTION											
NAPHTHALENE	0.65	0.15	0.95	0.84	2.10	ND, <0.09	6.68	13.48	9.89	7.91	27.56
2-METHYLNAPHTHALENE	TRACE	ND, <0.00	ND, <0.03	TRACE	ND, <0.03	ND, <0.09	ND, <0.12	TRACE	ND, <0.26	ND, <0.29	5.18
ACENAPHTHYLENE	TRACE	TRACE	TRACE	TRACE	ND, <0.03	ND, <0.09	ND, <0.12	ND, <0.22	TRACE	TRACE	TRACE
ACENAPHTHENE	ND, <0.01	ND, <0.00	ND, <0.03	ND, <0.01	ND, <0.03	ND, <0.09	ND, <0.12	ND, <0.22	ND, <0.26	ND, <0.29	ND, <0.41
FLUORENE	ND, <0.01	ND, <0.00	ND, <0.03	ND, <0.01	ND, <0.03	ND, <0.09	ND, <0.12	ND, <0.22	ND, <0.26	ND, <0.29	ND, <0.41
PHENANTHRENE	0.25	0.13	0.31	0.77	0.41	1.04	3.17	15.60	40.30	75.83	172.81
ANTHRACENE	0.07	0.02	0.10	0.08	TRACE	0.39	0.70	2.16	4.37	7.23	13.30
FLUORANTHENE	1.30	0.31	2.03	1.55	2.36	8.16	16.32	35.68	42.37	52.06	59.35
PYRENE	3.85	1.10	6.61	5.60	6.90	20.18	33.22	60.54	76.80	98.34	122.80
BENZO(A)ANTHRACENE	0.62	0.22	1.23	1.77	1.68	3.18	3.90	5.41	4.50	5.06	5.53
CHRYSENE	0.85	0.35	1.91	2.87	3.37	6.44	7.58	9.95	8.87	10.85	11.67
BENZO(B)FLUORANTHENE	0.33	0.16	0.89	1.77	2.19	3.48	3.85	4.87	3.44	3.76	4.09
BENZO(K)FLUORANTHENE	0.47	0.17	1.05	1.62	1.68	2.92	3.15	4.22	2.78	2.89	3.27
BENZO(E)PYRENE	0.28	0.11	0.62	1.25	1.62	4.21	2.62	3.24	3.97	2.89	4.09
BENZO(A)PYRENE	0.47	0.14	0.90	0.88	0.50	2.15	2.27	4.22	3.71	3.18	3.89
PERYLENE	0.06	0.02	0.11	0.06	TRACE	TRACE	TRACE	TRACE	ND, <0.26	TRACE	ND, <0.41
INDENO(123-CD)PYRENE	0.41	0.14	0.81	1.03	0.91	1.55	1.87	2.92	1.32	1.45	1.43
DIBENZ(AH)ANTHRACENE	0.05	0.01	TRACE	0.13	0.13	0.30	TRACE	TRACE	ND, <0.26	ND, <0.29	ND, <0.41
BENZO(GHI)PERYLENE	0.48	0.16	1.00	1.03	0.94	2.23	2.39	3.78	2.38	2.31	2.66
VAPOR FRACTION											
NAPHTHALENE	370.36	146.55	1110.48	496.53	377.14	1262.38	2005.31	3287.35	3893.73	4252.60	5609.27
2-METHYLNAPHTHALENE	207.66	71.66	389.70	225.94	162.82	544.05	528.82	851.21	1214.64	1543.51	1877.49
ACENAPHTHYLENE	26.79	11.19	107.13	31.17	29.15	104.40	83.46	133.19	163.13	163.70	180.52
ACENAPHTHENE	7.92	3.45	26.66	11.77	9.40	15.81	ND, <0.12	ND, <0.22	ND, <0.26	ND, <0.29	ND, <0.41
FLUORENE	18.78	9.28	49.76	30.32	23.84	52.22	34.17	46.09	64.40	83.35	111.82
PHENANTHRENE	51.93	26.47	121.60	102.18	81.99	234.86	237.27	321.20	433.11	501.95	628.54
ANTHRACENE	4.44	2.09	8.58	6.52	5.13	15.67	16.03	18.92	21.85	23.86	23.54
FLUORANTHENE	4.24	2.56	11.80	14.21	9.07	23.98	30.81	33.37	34.25	25.84	20.19
PYRENE	8.67	5.54	21.99	31.90	20.72	48.55	42.02	41.19	41.18	39.19	26.81
BENZO(A)ANTHRACENE	ND, <0.01	ND, <0.00	ND, <0.03	ND, <0.01	ND, <0.03	ND, <0.09	ND, <0.12	ND, <0.22	ND, <0.26	ND, <0.29	ND, <0.41
CHRYSENE	ND, <0.01	ND, <0.00	ND, <0.03	ND, <0.01	ND, <0.03	ND, <0.09	ND, <0.12	ND, <0.22	ND, <0.26	ND, <0.29	ND, <0.41
BENZO(B)FLUORANTHENE	ND, <0.01	ND, <0.00	ND, <0.03	ND, <0.01	ND, <0.03	ND, <0.09	ND, <0.12	ND, <0.22	ND, <0.26	ND, <0.29	ND, <0.41
BENZO(K)FLUORANTHENE	ND, <0.01	ND, <0.00	ND, <0.03	ND, <0.01	ND, <0.03	ND, <0.09	ND, <0.12	ND, <0.22	ND, <0.26	ND, <0.29	ND, <0.41
BENZO(E)PYRENE	ND, <0.01	ND, <0.00	ND, <0.03	ND, <0.01	ND, <0.03	ND, <0.09	ND, <0.12	ND, <0.22	ND, <0.26	ND, <0.29	ND, <0.41
BENZO(A)PYRENE	ND, <0.01	ND, <0.00	ND, <0.03	ND, <0.01	ND, <0.03	ND, <0.09	ND, <0.12	ND, <0.22	ND, <0.26	ND, <0.29	ND, <0.41
PERYLENE	ND, <0.01	ND, <0.00	ND, <0.03	ND, <0.01	ND, <0.03	ND, <0.09	ND, <0.12	ND, <0.22	ND, <0.26	ND, <0.29	ND, <0.41
INDENO(123-CD)PYRENE	ND, <0.01	ND, <0.00	ND, <0.03	ND, <0.01	ND, <0.03	ND, <0.09	ND, <0.12	ND, <0.22	ND, <0.26	ND, <0.29	ND, <0.41
DIBENZ(AH)ANTHRACENE	ND, <0.01	ND, <0.00	ND, <0.03	ND, <0.01	ND, <0.03	ND, <0.09	ND, <0.12	ND, <0.22	ND, <0.26	ND, <0.29	ND, <0.41
BENZO(GHI)PERYLENE	ND, <0.01	ND, <0.00	ND, <0.03	ND, <0.01	ND, <0.03	ND, <0.09	ND, <0.12	ND, <0.22	ND, <0.26	ND, <0.29	ND, <0.41

APPENDIX I-9: LOCOMOTIVE UP9715
High-Sulfur, Nonroad Diesel

PAH PRODUCTION , mg/hr											
COMPOUND NAME	**Notch low idle**	**Notch idle**	**Notch DB**	**Notch 1.00**	**Notch 2.00**	**Notch 3.00**	**Notch 4.00**	**Notch 5.00**	**Notch 6.00**	**Notch 7.00**	**Notch 8.00**
PARTICULATE FRACTION											
NAPHTHALENE	0.67	1.07	0.91	1.50	2.46	4.25	13.36	23.08	44.81	14.95	15.89
2-METHYLNAPHTHALENE	ND, <0.02	ND, <0.01	ND, <0.02	TRACE	ND, <0.03	ND, <0.08	2.10	4.46	8.25	ND, <0.32	ND, <0.00
ACENAPHTHYLENE	TRACE	TRACE	TRACE	ND, <0.02	ND, <0.03	ND, <0.08	ND, <0.12	ND, <0.20	ND, <0.25	TRACE	0.75
ACENAPHTHENE	ND, <0.02	ND, <0.01	ND, <0.02	ND, <0.02	ND, <0.03	ND, <0.08	ND, <0.12	ND, <0.20	ND, <0.25	ND, <0.32	ND, <0.00
FLUORENE	ND, <0.02	ND, <0.01	ND, <0.02	ND, <0.02	ND, <0.03	ND, <0.08	ND, <0.12	ND, <0.20	ND, <0.25	ND, <0.32	ND, <0.00
PHENANTHRENE	3.75	1.27	1.00	0.81	ND, <0.03	ND, <0.08	0.38	9.28	5.60	18.06	53.37
ANTHRACENE	0.33	0.15	0.16	0.09	TRACE	TRACE	TRACE	TRACE	0.88	1.90	2.44
FLUORANTHENE	3.64	1.87	2.39	1.63	2.04	8.13	11.89	27.54	37.90	36.33	60.06
PYRENE	7.04	3.66	4.11	2.83	3.41	11.79	15.46	22.62	42.96	22.11	26.28
BENZO(A)ANTHRACENE	1.82	1.24	1.72	1.80	1.36	3.25	2.91	3.54	7.33	3.16	4.69
CHRYSENE	4.11	2.70	3.44	5.40	4.77	8.94	8.32	10.82	17.69	13.27	22.52
BENZO(B)FLUORANTHENE	0.95	0.83	1.15	1.63	2.04	3.58	2.97	4.52	7.58	4.26	8.26
BENZO(K)FLUORANTHENE	1.03	0.83	1.15	1.63	1.70	2.97	3.63	3.93	7.45	3.32	6.19
BENZO(E)PYRENE	0.78	0.83	0.94	0.94	1.12	2.44	2.14	3.44	5.18	3.00	6.94
BENZO(A)PYRENE	0.79	0.64	0.64	0.15	0.20	0.98	1.66	2.66	2.78	1.90	6.38
PERYLENE	0.08	TRACE	ND, <0.02	ND, <0.02	ND, <0.03	ND, <0.08	ND, <0.12	ND, <0.20	ND, <0.25	ND, <0.32	ND, <0.00
INDENO(123-CD)PYRENE	0.71	0.68	0.78	0.44	0.37	1.26	1.19	1.48	3.41	1.42	2.82
DIBENZ(AH)ANTHRACENE	0.10	0.08	0.09	0.08	TRACE	TRACE	TRACE	TRACE	TRACE	ND, <0.32	0.75
BENZO(GHI)PERYLENE	0.79	0.83	0.93	0.21	0.24	1.26	1.13	1.77	3.66	1.74	4.32
VAPOR FRACTION											
NAPHTHALENE	644.04	597.42	548.88	226.27	211.27	748.23	796.98	1417.11	3083.69	3539.10	3079.57
2-METHYLNAPHTHALENE	369.25	260.48	207.23	202.85	181.75	433.87	366.98	567.89	1601.23	2001.73	1383.99
ACENAPHTHYLENE	54.05	50.69	57.67	23.41	24.39	90.73	61.35	121.19	244.10	194.59	174.94
ACENAPHTHENE	15.02	10.36	10.50	6.16	5.08	7.66	ND, <0.12	ND, <0.20	ND, <0.25	ND, <0.32	ND, <0.38
FLUORENE	67.38	40.91	35.53	35.27	24.12	45.38	26.53	42.92	111.99	133.68	89.41
PHENANTHRENE	165.12	95.91	76.21	93.15	82.95	202.07	170.67	262.73	653.34	611.42	463.81
ANTHRACENE	15.31	9.92	8.37	8.87	7.07	18.09	12.78	17.21	39.80	18.16	ND, <0.38
FLUORANTHENE	8.93	9.19	7.92	7.70	5.77	17.83	13.59	18.56	49.11	32.96	16.64
PYRENE	9.74	9.89	7.85	8.83	6.32	15.89	10.17	11.90	30.45	17.53	ND, <0.38
BENZO(A)ANTHRACENE	ND, <0.02	ND, <0.01	ND, <0.02	ND, <0.02	ND, <0.03	ND, <0.08	ND, <0.12	ND, <0.20	ND, <0.25	ND, <0.32	ND, <0.38
CHRYSENE	ND, <0.02	ND, <0.01	ND, <0.02	ND, <0.02	ND, <0.03	ND, <0.08	ND, <0.12	ND, <0.20	ND, <0.25	ND, <0.32	ND, <0.38
BENZO(B)FLUORANTHENE	ND, <0.02	ND, <0.01	ND, <0.02	ND, <0.02	ND, <0.03	ND, <0.08	ND, <0.12	ND, <0.20	ND, <0.25	ND, <0.32	ND, <0.38
BENZO(K)FLUORANTHENE	ND, <0.02	ND, <0.01	ND, <0.02	ND, <0.02	ND, <0.03	ND, <0.08	ND, <0.12	ND, <0.20	ND, <0.25	ND, <0.32	ND, <0.38
BENZO(E)PYRENE	ND, <0.02	ND, <0.01	ND, <0.02	ND, <0.02	ND, <0.03	ND, <0.08	ND, <0.12	ND, <0.20	ND, <0.25	ND, <0.32	ND, <0.38
BENZO(A)PYRENE	ND, <0.02	ND, <0.01	ND, <0.02	ND, <0.02	ND, <0.03	ND, <0.08	ND, <0.12	ND, <0.20	ND, <0.25	ND, <0.32	ND, <0.38
PERYLENE	ND, <0.02	ND, <0.01	ND, <0.02	ND, <0.02	ND, <0.03	ND, <0.08	ND, <0.12	ND, <0.20	ND, <0.25	ND, <0.32	ND, <0.38
INDENO(123-CD)PYRENE	ND, <0.02	ND, <0.01	ND, <0.02	ND, <0.02	ND, <0.03	ND, <0.08	ND, <0.12	ND, <0.20	ND, <0.25	ND, <0.32	ND, <0.38
DIBENZ(AH)ANTHRACENE	ND, <0.02	ND, <0.01	ND, <0.02	ND, <0.02	ND, <0.03	ND, <0.08	ND, <0.12	ND, <0.20	ND, <0.25	ND, <0.32	ND, <0.38
BENZO(GHI)PERYLENE	ND, <0.02	ND, <0.01	ND, <0.02	ND, <0.02	ND, <0.03	ND, <0.08	ND, <0.12	ND, <0.20	ND, <0.25	ND, <0.32	ND, <0.38

APPENDIX I-10: LOCOMOTIVE UP9724
CARB Diesel

PAH PRODUCTION , mg/hr											
COMPOUND NAME	**Notch low idle**	**Notch idle**	**Notch DB**	**Notch 1.00**	**Notch 2.00**	**Notch 3.00**	**Notch 4.00**	**Notch 5.00**	**Notch 6.00**	**Notch 7.00**	**Notch 8.00**
PARTICULATE FRACTION											
NAPHTHALENE	2.58	1.04	4.92	3.63	7.04	5.18	9.38	ND, <0.20	44.43	60.81	81.46
2-METHYLNAPHTHALENE	1.56	0.70	2.55	1.92	3.37	2.59	4.51	ND, <0.20	17.42	25.10	39.13
ACENAPHTHYLENE	0.07	0.06	TRACE	TRACE	TRACE	ND, <0.10	TRACE	ND, <0.20	TRACE	TRACE	TRACE
ACENAPHTHENE	0.22	0.06	0.44	0.37	0.58	0.48	0.83	ND, <0.20	3.68	4.99	9.38
FLUORENE	0.12	0.06	0.12	0.11	0.16	ND, <0.10	TRACE	ND, <0.20	0.89	1.29	1.80
PHENANTHRENE	2.42	1.72	1.98	1.89	2.94	3.17	7.24	3.65	11.39	19.63	32.34
ANTHRACENE	0.29	0.22	0.20	0.12	0.29	TRACE	0.65	TRACE	1.00	1.77	3.19
FLUORANTHENE	3.04	3.64	3.64	8.90	5.62	8.64	26.71	21.30	29.03	37.00	65.88
PYRENE	4.81	3.97	5.72	13.36	8.88	15.36	40.95	32.45	45.77	57.92	89.84
BENZO(A)ANTHRACENE	1.96	2.11	1.82	1.51	4.71	2.54	4.87	3.96	4.91	3.54	6.79
CHRYSENE	2.66	2.75	2.60	5.16	3.99	4.80	8.90	7.61	8.93	7.24	12.98
BENZO(B)FLUORANTHENE	1.20	1.94	1.17	2.40	3.63	3.17	6.53	5.78	4.69	3.22	6.59
BENZO(K)FLUORANTHENE	1.58	1.21	1.56	2.94	15.59	2.83	3.86	4.06	4.69	3.06	5.59
BENZO(E)PYRENE	1.08	0.89	0.96	1.42	4.90	3.12	4.39	3.45	5.36	4.34	9.38
BENZO(A)PYRENE	1.71	1.30	1.30	1.07	1.81	1.58	2.97	3.75	3.91	3.06	7.99
PERYLENE	0.23	0.14	0.18	TRACE	TRACE	TRACE	TRACE	TRACE	TRACE	ND, <0.32	ND, <0.40
INDENO(123-CD)PYRENE	1.52	1.30	1.27	1.25	1.99	1.82	3.15	2.84	2.90	1.93	4.99
DIBENZ(AH)ANTHRACENE	0.21	0.12	0.10	0.16	0.24	TRACE	0.47	TRACE	TRACE	ND, <0.32	TRACE
BENZO(GHI)PERYLENE	1.77	1.46	1.56	4.81	3.08	2.54	4.57	3.96	4.02	2.90	6.79
VAPOR FRACTION											
NAPHTHALENE	738.62	685.04	697.10	290.27	391.64	1084.66	1756.71	2494.92	848.44	1705.31	3114.56
2-METHYLNAPHTHALENE	562.52	532.81	647.68	167.40	177.69	470.34	700.31	892.49	200.95	1093.97	1557.28
ACENAPHTHYLENE	62.96	72.38	79.84	43.09	60.54	126.66	121.01	196.65	66.87	122.11	187.47
ACENAPHTHENE	7.69	6.75	6.81	3.69	5.15	5.95	ND, <0.12	ND, <0.20	ND, <0.22	ND, <0.32	ND, <0.40
FLUORENE	49.92	46.80	45.26	25.64	26.83	47.03	43.92	58.82	18.98	45.05	65.88
PHENANTHRENE	92.93	102.59	103.65	78.98	99.18	209.73	271.22	402.64	186.43	413.46	573.00
ANTHRACENE	11.26	13.58	12.19	10.48	12.46	25.29	29.50	43.31	19.76	39.74	51.31
FLUORANTHENE	8.97	13.09	11.91	9.94	15.34	30.52	34.18	56.39	25.23	50.84	55.10
PYRENE	12.70	17.04	14.37	15.18	18.22	33.84	34.13	56.29	24.00	50.68	52.91
BENZO(A)ANTHRACENE	ND, <0.01	ND, <0.02	ND, <0.03	ND, <0.02	ND, <0.04	ND, <0.10	ND, <0.12	ND, <0.20	ND, <0.22	ND, <0.32	ND, <0.40
CHRYSENE	ND, <0.01	ND, <0.02	ND, <0.03	ND, <0.02	ND, <0.04	ND, <0.10	ND, <0.12	ND, <0.20	ND, <0.22	ND, <0.32	ND, <0.40
BENZO(B)FLUORANTHENE	ND, <0.01	ND, <0.02	ND, <0.03	ND, <0.02	ND, <0.04	ND, <0.10	ND, <0.12	ND, <0.20	ND, <0.22	ND, <0.32	ND, <0.40
BENZO(K)FLUORANTHENE	ND, <0.01	ND, <0.02	ND, <0.03	ND, <0.02	ND, <0.04	ND, <0.10	ND, <0.12	ND, <0.20	ND, <0.22	ND, <0.32	ND, <0.40
BENZO(E)PYRENE	ND, <0.01	ND, <0.02	ND, <0.03	ND, <0.02	ND, <0.04	ND, <0.10	ND, <0.12	ND, <0.20	ND, <0.22	ND, <0.32	ND, <0.40
BENZO(A)PYRENE	ND, <0.01	ND, <0.02	ND, <0.03	ND, <0.02	ND, <0.04	ND, <0.10	ND, <0.12	ND, <0.20	ND, <0.22	ND, <0.32	ND, <0.40
PERYLENE	ND, <0.01	ND, <0.02	ND, <0.03	ND, <0.02	ND, <0.04	ND, <0.10	ND, <0.12	ND, <0.20	ND, <0.22	ND, <0.32	ND, <0.40
INDENO(123-CD)PYRENE	ND, <0.01	ND, <0.02	ND, <0.03	ND, <0.02	ND, <0.04	ND, <0.10	ND, <0.12	ND, <0.20	ND, <0.22	ND, <0.32	ND, <0.40
DIBENZ(AH)ANTHRACENE	ND, <0.01	ND, <0.02	ND, <0.03	ND, <0.02	ND, <0.04	ND, <0.10	ND, <0.12	ND, <0.20	ND, <0.22	ND, <0.32	ND, <0.40
BENZO(GHI)PERYLENE	ND, <0.01	ND, <0.02	ND, <0.03	ND, <0.02	ND, <0.04	ND, <0.10	ND, <0.12	ND, <0.20	ND, <0.22	ND, <0.32	ND, <0.40

APPENDIX I-11: LOCOMOTIVE UP9724

On-Highway Diesel

PAH PRODUCTION , mg/hr											
COMPOUND NAME	**Notch low idle**	**Notch idle**	**Notch DB**	**Notch 1.00**	**Notch 2.00**	**Notch 3.00**	**Notch 4.00**	**Notch 5.00**	**Notch 6.00**	**Notch 7.00**	**Notch 8.00**
PARTICULATE FRACTION											
NAPHTHALENE	0.27	1.30	3.33	1.23	4.30	10.06	22.58	TRACE	43.76	62.77	79.29
2-METHYLNAPHTHALENE	0.62	0.59	1.52	0.67	1.93	4.89	9.99	2.02	22.11	31.71	40.05
ACENAPHTHYLENE	0.07	0.05	0.08	TRACE	TRACE	ND, <0.09	TRACE	ND, <0.22	TRACE	TRACE	TRACE
ACENAPHTHENE	ND, <0.01	0.09	0.25	0.12	0.28	0.92	2.04	ND, <0.22	4.40	6.31	7.97
FLUORENE	0.08	0.06	0.22	0.28	0.20	TRACE	0.45	ND, <0.22	1.02	1.46	1.84
PHENANTHRENE	9.28	2.89	11.08	6.53	7.36	7.47	9.19	6.50	26.17	37.53	47.41
ANTHRACENE	0.62	0.26	0.83	0.25	0.50	0.60	0.68	TRACE	1.92	2.75	3.47
FLUORANTHENE	6.40	4.66	7.49	6.21	10.49	20.29	20.99	20.17	31.58	45.30	57.22
PYRENE	15.81	9.31	18.99	12.41	21.65	38.28	37.45	39.22	56.39	80.89	102.18
BENZO(A)ANTHRACENE	2.44	2.56	3.91	4.81	4.83	5.07	5.22	5.04	4.62	6.63	8.38
CHRYSENE	3.16	3.57	5.25	7.76	8.33	9.69	10.21	8.74	9.02	12.94	16.35
BENZO(B)FLUORANTHENE	1.08	2.17	2.01	9.31	7.00	7.38	4.48	3.59	3.16	4.53	5.72
BENZO(K)FLUORANTHENE	1.08	1.86	5.47	0.06	5.16	5.07	5.05	4.48	3.50	5.02	6.33
BENZO(E)PYRENE	1.01	1.47	1.68	4.50	9.83	6.00	5.45	3.92	3.83	5.50	6.95
BENZO(A)PYRENE	1.58	1.47	2.23	1.63	3.33	3.04	3.23	3.70	3.50	5.02	6.33
PERYLENE	0.21	0.17	0.11	0.14	TRACE	TRACE	0.40	TRACE	TRACE	TRACE	ND, <0.41
INDENO(123-CD)PYRENE	1.44	1.63	2.46	2.33	2.83	3.32	3.46	3.25	2.71	3.88	4.90
DIBENZ(AH)ANTHRACENE	0.16	0.16	0.25	0.28	0.52	0.37	0.51	TRACE	TRACE	TRACE	TRACE
BENZO(GHI)PERYLENE	1.51	2.02	2.46	3.10	4.16	4.61	4.54	4.03	3.50	5.02	6.33
VAPOR FRACTION											
NAPHTHALENE	1269.01	1215.57	1414.47	687.35	842.84	2241.62	2587.14	3989.07	3676.85	4626.95	5435.81
2-METHYLNAPHTHALENE	688.40	448.66	601.09	161.36	179.90	244.46	442.54	605.08	879.74	938.33	1185.25
ACENAPHTHYLENE	172.02	193.58	211.60	108.14	140.57	260.09	246.17	340.53	387.87	410.76	477.98
ACENAPHTHENE	54.71	46.68	51.55	30.36	31.88	36.62	ND, <0.11	ND, <0.22	ND, <0.23	ND, <0.32	ND, <0.41
FLUORENE	135.67	123.27	155.08	75.10	74.62	95.94	95.32	121.02	166.92	207.08	261.57
PHENANTHRENE	306.62	292.41	309.15	230.18	244.36	399.89	520.26	747.39	1011.70	1240.86	1342.60
ANTHRACENE	24.98	29.32	25.44	18.44	282.79	40.91	45.22	71.38	86.51	93.35	101.56
FLUORANTHENE	16.64	27.29	19.17	31.16	30.25	41.33	57.64	94.80	93.16	96.42	97.27
PYRENE	33.09	51.27	32.46	61.33	53.39	64.80	85.39	112.61	135.91	143.18	119.55
BENZO(A)ANTHRACENE	ND, <0.01	ND, <0.02	ND, <0.02	ND, <0.02	ND, <0.03	ND, <0.09	ND, <0.11	ND, <0.22	ND, <0.23	ND, <0.32	ND, <0.41
CHRYSENE	ND, <0.01	ND, <0.02	ND, <0.02	ND, <0.02	ND, <0.03	ND, <0.09	ND, <0.11	ND, <0.22	ND, <0.23	ND, <0.32	ND, <0.41
BENZO(B)FLUORANTHENE	ND, <0.01	ND, <0.02	ND, <0.02	ND, <0.02	ND, <0.03	ND, <0.09	ND, <0.11	ND, <0.22	ND, <0.23	ND, <0.32	ND, <0.41
BENZO(K)FLUORANTHENE	ND, <0.01	ND, <0.02	ND, <0.02	ND, <0.02	ND, <0.03	ND, <0.09	ND, <0.11	ND, <0.22	ND, <0.23	ND, <0.32	ND, <0.41
BENZO(E)PYRENE	ND, <0.01	ND, <0.02	ND, <0.02	ND, <0.02	ND, <0.03	ND, <0.09	ND, <0.11	ND, <0.22	ND, <0.23	ND, <0.32	ND, <0.41
BENZO(A)PYRENE	ND, <0.01	ND, <0.02	ND, <0.02	ND, <0.02	ND, <0.03	ND, <0.09	ND, <0.11	ND, <0.22	ND, <0.23	ND, <0.32	ND, <0.41
PERYLENE	ND, <0.01	ND, <0.02	ND, <0.02	ND, <0.02	ND, <0.03	ND, <0.09	ND, <0.11	ND, <0.22	ND, <0.23	ND, <0.32	ND, <0.41
INDENO(123-CD)PYRENE	ND, <0.01	ND, <0.02	ND, <0.02	ND, <0.02	ND, <0.03	ND, <0.09	ND, <0.11	ND, <0.22	ND, <0.23	ND, <0.32	ND, <0.41
DIBENZ(AH)ANTHRACENE	ND, <0.01	ND, <0.02	ND, <0.02	ND, <0.02	ND, <0.03	ND, <0.09	ND, <0.11	ND, <0.22	ND, <0.23	ND, <0.32	ND, <0.41
BENZO(GHI)PERYLENE	ND, <0.01	ND, <0.02	ND, <0.02	ND, <0.02	ND, <0.03	ND, <0.09	ND, <0.11	ND, <0.22	ND, <0.23	ND, <0.32	ND, <0.41

APPENDIX I-12: LOCOMOTIVE UP9724
High-Sulfur Nonroad Diesel

PAH PRODUCTION , mg/hr											
COMPOUND NAME	**Notch low idle**	**Notch idle**	**Notch DB**	**Notch 1.00**	**Notch 2.00**	**Notch 3.00**	**Notch 4.00**	**Notch 5.00**	**Notch 6.00**	**Notch 7.00**	**Notch 8.00**
PARTICULATE FRACTION											
NAPHTHALENE	1.38	1.56	3.71	2.14	5.45	9.63	7.24	14.09	ND, <0.26	18.54	66.79
2-METHYLNAPHTHALENE	0.59	0.55	1.41	0.96	2.30	5.37	3.28	6.78	ND, <0.26	9.43	29.33
ACENAPHTHYLENE	TRACE	TRACE	TRACE	TRACE	TRACE	ND, <0.09	ND, <0.11	ND, <0.18	ND, <0.26	TRACE	0.71
ACENAPHTHENE	0.11	0.11	0.31	0.18	0.42	1.02	0.57	1.16	ND, <0.26	1.89	6.71
FLUORENE	0.08	TRACE	0.16	0.07	TRACE	TRACE	TRACE	ND, <0.18	ND, <0.26	TRACE	1.59
PHENANTHRENE	3.90	2.03	6.83	1.91	3.14	5.65	5.09	7.22	7.65	17.59	28.63
ANTHRACENE	0.32	0.21	0.65	0.14	0.26	0.51	0.45	0.62	TRACE	1.41	1.24
FLUORANTHENE	2.67	3.59	9.87	2.88	6.95	18.99	20.92	26.75	27.71	51.84	56.54
PYRENE	3.95	5.28	13.34	4.24	8.96	26.40	28.27	35.67	31.67	50.27	53.01
BENZO(A)ANTHRACENE	2.45	2.00	4.67	3.70	3.29	6.95	4.35	6.96	4.49	6.28	5.30
CHRYSENE	3.45	2.64	7.34	3.42	7.68	14.36	11.87	16.05	11.61	20.42	17.67
BENZO(B)FLUORANTHENE	1.22	1.58	2.67	1.62	5.12	6.48	7.92	6.24	4.35	7.85	6.01
BENZO(K)FLUORANTHENE	1.39	1.27	3.47	4.78	2.38	6.95	3.85	5.35	3.83	5.50	4.59
BENZO(E)PYRENE	0.95	1.02	1.87	1.44	2.93	7.87	4.47	5.97	3.96	6.91	8.83
BENZO(A)PYRENE	1.17	1.06	2.13	0.11	0.22	1.02	0.62	1.16	0.92	1.41	2.12
PERYLENE	0.13	0.09	0.19	ND, <0.02	ND, <0.04	ND, <0.09	ND, <0.11	ND, <0.18	ND, <0.26	ND, <0.31	ND, <0.00
INDENO(123-CD)PYRENE	1.39	1.48	2.40	0.89	1.37	3.61	2.49	3.92	2.90	4.24	4.24
DIBENZ(AH)ANTHRACENE	0.17	0.15	0.23	0.15	0.26	0.51	0.45	0.62	TRACE	TRACE	0.35
BENZO(GHI)PERYLENE	1.45	1.58	2.67	0.74	1.48	3.84	2.60	3.75	2.37	3.30	ND, <0.00
VAPOR FRACTION											
NAPHTHALENE	648.40	818.69	968.69	311.83	266.95	1093.04	1221.38	1837.05	2981.94	2607.79	2844.65
2-METHYLNAPHTHALENE	254.69	2065.72	224.16	70.30	179.18	46.32	67.85	89.18	184.72	298.48	409.16
ACENAPHTHYLENE	144.24	178.71	185.98	88.67	70.19	242.65	183.15	253.17	321.81	336.03	358.31
ACENAPHTHENE	27.33	30.74	33.54	14.55	9.76	18.71	ND, <0.11	ND, <0.18	ND, <0.26	ND, <0.31	ND, <0.39
FLUORENE	82.75	95.80	119.82	52.99	61.80	68.55	61.07	78.48	109.51	125.68	151.97
PHENANTHRENE	181.67	228.62	262.45	141.22	195.09	313.55	382.81	541.30	708.54	686.51	812.48
ANTHRACENE	21.00	27.19	30.38	15.11	21.52	31.82	34.89	53.24	65.58	43.52	61.76
FLUORANTHENE	17.88	30.76	28.23	24.48	18.58	51.69	68.76	99.52	111.62	104.63	104.43
PYRENE	19.49	32.76	28.09	26.18	20.20	46.55	51.17	78.92	82.47	69.91	75.01
BENZO(A)ANTHRACENE	ND, <0.01	ND, <0.02	ND, <0.03	ND, <0.02	ND, <0.04	ND, <0.09	ND, <0.11	ND, <0.18	ND, <0.26	ND, <0.31	ND, <0.39
CHRYSENE	ND, <0.01	ND, <0.02	ND, <0.03	ND, <0.02	ND, <0.04	ND, <0.09	ND, <0.11	ND, <0.18	ND, <0.26	ND, <0.31	ND, <0.39
BENZO(B)FLUORANTHENE	ND, <0.01	ND, <0.02	ND, <0.03	ND, <0.02	ND, <0.04	ND, <0.09	ND, <0.11	ND, <0.18	ND, <0.26	ND, <0.31	ND, <0.39
BENZO(K)FLUORANTHENE	ND, <0.01	ND, <0.02	ND, <0.03	ND, <0.02	ND, <0.04	ND, <0.09	ND, <0.11	ND, <0.18	ND, <0.26	ND, <0.31	ND, <0.39
BENZO(E)PYRENE	ND, <0.01	ND, <0.02	ND, <0.03	ND, <0.02	ND, <0.04	ND, <0.09	ND, <0.11	ND, <0.18	ND, <0.26	ND, <0.31	ND, <0.39
BENZO(A)PYRENE	ND, <0.01	ND, <0.02	ND, <0.03	ND, <0.02	ND, <0.04	ND, <0.09	ND, <0.11	ND, <0.18	ND, <0.26	ND, <0.31	ND, <0.39
PERYLENE	ND, <0.01	ND, <0.02	ND, <0.03	ND, <0.02	ND, <0.04	ND, <0.09	ND, <0.11	ND, <0.18	ND, <0.26	ND, <0.31	ND, <0.39
INDENO(123-CD)PYRENE	ND, <0.01	ND, <0.02	ND, <0.03	ND, <0.02	ND, <0.04	ND, <0.09	ND, <0.11	ND, <0.18	ND, <0.26	ND, <0.31	ND, <0.39
DIBENZ(AH)ANTHRACENE	ND, <0.01	ND, <0.02	ND, <0.03	ND, <0.02	ND, <0.04	ND, <0.09	ND, <0.11	ND, <0.18	ND, <0.26	ND, <0.31	ND, <0.39
BENZO(GHI)PERYLENE	ND, <0.01	ND, <0.02	ND, <0.03	ND, <0.02	ND, <0.04	ND, <0.09	ND, <0.11	ND, <0.18	ND, <0.26	ND, <0.31	ND, <0.39

APPENDIX J

Volatile Organic Fraction (VOF) of Particulate Data

Appendix J. Volatile Organic Fraction (VOF) of Particulate Data

BNSF 9693

	CARB diesel (EM-2663-F)				On-Hwy Diesel (EM-2677-F)				High Sulfur, Nonroad diesel (EM-2664-F)			
TEST NO.	Total Part., g/hp-hr	% VOF	VOF, g/hp-hr	Unburned OIL, %	Total Part. g/hp-hr	% VOF	VOF, g/hp-hr	Unburned OIL, %	Total Part. g/hp-hr	% VOF	VOF, g/hp-hr	Unburned OIL, %
DB-2	2.592	67.1	1.740	81	2.504	51.8	1.297	71	2.831	61.6	1.744	72
Idle	1.355	57.5	0.779	65	3.125	20.3	0.634	56	1.290	58.6	0.756	53
Notch 1	0.317	63.5	0.201	77	0.276	58.5	0.161	84	0.243	57.4	0.139	67
Notch 2	0.259	64.4	0.167	94	0.228	61.1	0.139	96	0.228	54.7	0.125	83
Notch 3	0.282	66.9	0.189	99	0.221	60.1	0.133	97	0.293	59.8	0.175	90
Notch 4	0.270	54.2	0.146	89	0.239	49.4	0.118	96	0.300	78.0	0.234	88
Notch 5	0.271	43.4	0.118	86	0.261	45.7	0.119	95	0.327	43.3	0.142	88
Notch 6	0.291	31.9	0.093	78	0.350	31.9	0.111	92	0.396	30.9	0.122	89
Notch 7	0.287	51.1	0.147	82	0.300	32.3	0.097	100	0.404	30.9	0.125	90
Notch 8	0.481	59.4	0.286	87	0.493	56.5	0.279	96	0.587	53.8	0.316	94

BNSF 9754

	CARB diesel (EM-2663-F)				On-Hwy Diesel (EM-2677-F)				High Sulfur, Nonroad diesel (EM-2664-F)			
TEST NO.	Total Part., g/hp-hr	% VOF	VOF, g/hp-hr	Unburned OIL, %	Total Part. g/hp-hr	% VOF	VOF, g/hp-hr	Unburned OIL, %	Total Part. g/hp-hr	% VOF	VOF, g/hp-hr	Unburned OIL, %
DB-2	3.457	56.3	1.947	83	2.386	58.5	1.397	77	3.030	58.7	1.779	77
Idle	1.299	59.0	0.766	67	1.542	45.9	0.707	66	1.795	42.9	0.771	73
Notch 1	0.444	59.3	0.263	83	0.325	59.5	0.193	85	0.468	56.0	0.262	81
Notch 2	0.305	66.9	0.204	85	0.293	61.0	0.179	90	0.355	58.4	0.207	80
Notch 3	0.393	56.2	0.221	95	0.362	61.7	0.223	98	0.262	86.2	0.226	94
Notch 4	0.310	55.2	0.171	93	0.309	56.1	0.173	94	0.400	45.8	0.183	94
Notch 5	0.300	53.9	0.162	90	0.280	54.4	0.152	90	0.368	43.9	0.161	90
Notch 6	0.353	47.4	0.167	88	0.339	44.5	0.151	89	0.438	34.4	0.151	88
Notch 7	0.366	52.8	0.193	89	0.368	49.2	0.181	90	0.425	47.0	0.200	87
Notch 8	0.378	49.7	0.188	88	0.392	50.1	0.197	89	0.432	47.9	0.207	90

BNSF 9696

	CARB diesel (EM-2663-F)				On-Hwy Diesel (EM-2677-F)				High Sulfur, Nonroad diesel (EM-2664-F)			
TEST NO.	Total Part., g/hp-hr	% VOF	VOF, g/hp-hr	Unburned OIL, %	Total Part. g/hp-hr	% VOF	VOF, g/hp-hr	Unburned OIL, %	Total Part. g/hp-hr	% VOF	VOF, g/hp-hr	Unburned OIL, %
DB-2	1.933	66.6	1.288	62	2.418	54.3	1.312	60	2.337	39.2	0.915	47
Idle	0.980	58.6	0.574	48	1.087	56.5	0.614	46	1.399	59.6	0.834	70
Notch 1	0.205	68.4	0.140	65	0.243	66.7	0.162	65	0.208	58.0	0.121	60
Notch 2	0.211	67.1	0.141	77	0.249	62.2	0.155	77	0.240	51.5	0.124	68
Notch 3	0.234	68.5	0.160	89	0.282	68.1	0.192	92	0.276	54.4	0.150	80
Notch 4	0.245	39.9	0.098	100	0.261	51.2	0.134	93	0.350	30.2	0.106	83
Notch 5	0.244	36.5	0.089	81	0.258	37.1	0.096	87	0.339	22.6	0.077	73
Notch 6	0.202	59.2	0.120	76	0.231	54.8	0.127	84	0.295	37.2	0.110	79
Notch 7	0.215	67.5	0.145	85	0.242	65.8	0.159	92	0.262	52.8	0.138	79
Notch 8	0.213	69.5	0.148	80	0.244	60.4	0.147	87	0.297	49.0	0.146	83

UP 9715

	CARB diesel (EM-2663-F)				On-Hwy Diesel (EM-2677-F)				High Sulfur, Nonroad diesel (EM-2664-F)			
TEST NO.	Total Part., g/hp-hr	% VOF	VOF, g/hp-hr	Unburned OIL, %	Total Part. g/hp-hr	% VOF	VOF, g/hp-hr	Unburned OIL, %	Total Part. g/hp-hr	% VOF	VOF, g/hp-hr	Unburned OIL, %
DB-2	1.769	24.0	0.424	53	1.088	24.4	0.265	32	1.828	36.1	0.660	37
Low Idle	2.256	20.7	0.467	35	1.770	20.6	0.364	25	4.068	30.1	1.224	19
Idle	1.471	21.9	0.322	27	2.120	22.0	0.467	23	2.680	26.4	0.709	22
Notch 1	0.151	54.4	0.082	64	0.182	52.9	0.096	66	0.260	50.5	0.131	56
Notch 2	0.104	48.5	0.050	69	0.105	52.1	0.055	73	0.212	30.3	0.064	63
Notch 3	0.196	28.6	0.056	64	0.144	35.1	0.051	67	0.283	21.8	0.062	62
Notch 4	0.183	10.4	0.019	55	0.157	15.2	0.024	64	0.260	13.1	0.034	70
Notch 5	0.171	18.0	0.031	64	0.149	21.2	0.032	64	0.241	17.3	0.042	73
Notch 6	0.124	23.7	0.029	69	0.121	20.1	0.024	53	0.217	16.1	0.035	79
Notch 7	0.091	25.2	0.023	64	0.106	20.4	0.022	55	0.203	13.0	0.026	68
Notch 8	0.105	23.0	0.024	55	0.117	19.5	0.023	44	0.226	11.3	0.026	51

UP 9724

	CARB diesel (EM-2663-F)				On-Hwy Diesel (EM-2677-F)				High Sulfur, Nonroad diesel (EM-2664-F)			
TEST NO.	Total Part., g/hp-hr	% VOF	VOF, g/hp-hr	Unburned OIL, %	Total Part. g/hp-hr	% VOF	VOF, g/hp-hr	Unburned OIL, %	Total Part. g/hp-hr	% VOF	VOF, g/hp-hr	Unburned OIL, %
DB-2	2.247	44.4	0.999	46	3.435	75.0	2.577	80	3.855	41.2	1.588	48
Low Idle	4.266	25.7	1.095	28	5.245	79.2	4.152	62	3.617	30.3	1.095	34
Idle	3.513	38.9	1.365	42	3.251	28.9	0.939	38	3.471	29.1	1.010	38
Notch 1	0.379	56.4	0.214	68	0.550	15.4	0.085	27	0.353	49.6	0.175	64
Notch 2	0.316	48.7	0.154	74	0.418	31.6	0.132	65	0.323	36.1	0.117	77
Notch 3	0.236	31.2	0.074	66	0.241	30.7	0.074	65	0.334	20.1	0.067	53
Notch 4	0.222	13.7	0.030	52	0.196	16.6	0.033	55	0.296	10.5	0.031	45
Notch 5	0.166	22.3	0.037	54	0.141	23.9	0.034	51	0.229	14.4	0.033	47
Notch 6	0.113	27.1	0.031	47	0.106	26.0	0.028	52	0.195	16.3	0.032	42
Notch 7	0.085	27.6	0.023	46	0.092	30.0	0.028	43	0.206	16.3	0.034	40
Notch 8	0.085	26.6	0.023	40	0.087	36.4	0.032	39	0.212	16.5	0.035	37

UP 9733

	CARB diesel (EM-2663-F)				On-Hwy Diesel (EM-2677-F)				High Sulfur, Nonroad diesel (EM-2664-F)			
TEST NO.	Total Part., g/hp-hr	% VOF	VOF, g/hp-hr	Unburned OIL, %	Total Part. g/hp-hr	% VOF	VOF, g/hp-hr	Unburned OIL, %	Total Part. g/hp-hr	% VOF	VOF, g/hp-hr	Unburned OIL, %
DB-2	1.531	76.0	1.164	65	1.793	36.0	0.645	100	1.696	39.8	0.676	44
Low Idle	1.718	48.9	0.839	48	2.338	29.6	0.691	100	2.340	25.1	0.588	16
Idle	1.687	50.1	0.846	55	2.463	29.8	0.735	100	2.864	31.1	0.891	26
Notch 1	0.194	100.5	0.195	87	0.253	33.6	0.085	100	0.264	61.9	0.163	69
Notch 2	0.136	87.7	0.119	100	0.185	32.5	0.060	100	0.215	45.5	0.098	71
Notch 3	0.124	60.3	0.075	87	0.133	45.8	0.061	80	0.261	22.9	0.060	48
Notch 4	0.139	20.6	0.029	84	0.124	24.1	0.030	68	0.230	11.0	0.025	33
Notch 5	0.123	24.0	0.030	85	0.117	29.3	0.034	59	0.206	14.4	0.030	35
Notch 6	0.081	37.6	0.030	76	0.093	28.0	0.026	51	0.170	15.3	0.026	29
Notch 7	0.074	32.5	0.024	83	0.084	57.7	0.048	100	0.155	14.4	0.022	25
Notch 8	0.101	29.0	0.029	82	0.117	14.3	0.017	47	0.188	13.3	0.025	25

APPENDIX K

Metal Particulate Data

APPENDIX K-1: LOCOMOTIVE BN9693

CARB Diesel

METAL PM EMISSIONS, mg/hr										
COMPOUND NAME	Notch idle	Notch DB	Notch 1.00	Notch 2.00	Notch 3.00	Notch 4.00	Notch 5.00	Notch 6.00	Notch 7.00	Notch 8.00
ANTIMONY	ND, <68.3	ND, <130.5	ND, <109.3	ND, <103.1	ND, <168.0	ND, <228.8	ND, <285.1	ND, <518.9	ND, <567.5	ND, <651.1
ARSENIC	ND, <68.3	ND, <130.5	ND, <109.3	ND, <103.1	ND, <168.0	ND, <228.8	ND, <285.1	ND, <518.9	ND, <567.5	ND, <651.1
BERYLLIUM	ND, <13.7	ND, <26.1	ND, <21.9	ND, <20.6	ND, <33.6	ND, <45.8	ND, <57.0	ND, <103.8	ND, <113.5	ND, <130.2
CADMIUM	ND, <13.7	ND, <26.1	ND, <21.9	ND, <20.6	ND, <33.6	ND, <45.8	ND, <57.0	ND, <103.8	ND, <113.5	ND, <130.2
CHROMIUM	57.76	662.97	ND, <21.9	120.07	164.28	278.64	332.96	625.84	617.43	968.90
COBALT	ND, <13.7	ND, <26.1	ND, <21.9	ND, <20.6	ND, <33.6	ND, <45.8	ND, <57.0	ND, <103.8	ND, <113.5	ND, <130.2
COPPER	ND, <13.7	ND, <26.1	ND, <21.9	ND, <20.6	ND, <33.6	ND, <45.8	ND, <57.0	ND, <103.8	ND, <113.5	ND, <130.2
LEAD	ND, <41.0	ND, <78.3	ND, <65.6	ND, <61.9	ND, <100.8	ND, <137.3	ND, <171.0	ND, <311.4	ND, <340.5	ND, <390.7
MANGANESE	ND, <13.7	ND, <26.1	ND, <21.9	ND, <20.6	ND, <33.6	ND, <45.8	ND, <57.0	ND, <103.8	ND, <113.5	ND, <130.2
MERCURY	ND, <2.7	ND, <5.2	ND, <4.4	ND, <4.1	ND, <6.7	ND, <9.2	ND, <11.4	ND, <20.8	ND, <22.7	ND, <26.0
NICKEL	ND, <68.3	ND, <130.5	ND, <109.3	ND, <103.1	ND, <168.0	ND, <228.8	ND, <285.1	ND, <518.9	ND, <567.5	ND, <651.1
SELENIUM	ND, <68.3	ND, <130.5	ND, <109.3	ND, <103.1	ND, <168.0	ND, <228.8	ND, <285.1	ND, <518.9	ND, <567.5	ND, <651.1

ON-HIGHWAY DIESEL

METAL PM EMISSIONS, mg/hr										
COMPOUND NAME	Notch idle	Notch DB	Notch 1.00	Notch 2.00	Notch 3.00	Notch 4.00	Notch 5.00	Notch 6.00	Notch 7.00	Notch 8.00
ANTIMONY	ND, <91.8	ND, <128.8	ND, <106.8	ND, <132.4	ND, <164.0	ND, <232.6	ND, <330.3	ND, <434.5	ND, <614.4	ND, <698.8
ARSENIC	ND, <91.8	ND, <128.8	ND, <106.8	ND, <132.4	ND, <164.0	ND, <232.6	ND, <330.3	ND, <434.5	ND, <614.4	ND, <698.8
BERYLLIUM	ND, <18.4	ND, <25.8	ND, <21.4	ND, <26.5	ND, <32.8	ND, <46.5	ND, <66.1	ND, <86.9	ND, <122.9	ND, <139.8
CADMIUM	ND, <18.4	ND, <25.8	ND, <21.4	ND, <26.5	ND, <32.8	ND, <46.5	ND, <66.1	ND, <86.9	ND, <122.9	ND, <139.8
CHROMIUM	ND, <18.4	204.82	110.04	140.88	182.07	260.10	412.22	429.29	603.32	626.11
COBALT	ND, <18.4	ND, <25.8	ND, <21.4	ND, <26.5	ND, <32.8	ND, <46.5	ND, <66.1	ND, <86.9	ND, <122.9	ND, <139.8
COPPER	ND, <18.4	ND, <25.8	ND, <21.4	ND, <26.5	ND, <32.8	ND, <46.5	ND, <66.1	ND, <86.9	ND, <122.9	ND, <139.8
LEAD	ND, <55.1	ND, <77.3	ND, <64.1	ND, <79.4	ND, <98.4	ND, <139.6	ND, <198.2	ND, <260.7	ND, <368.6	ND, <419.3
MANGANESE	ND, <18.4	ND, <25.8	ND, <21.4	ND, <26.5	ND, <32.8	ND, <46.5	ND, <66.1	ND, <86.9	ND, <122.9	ND, <139.8
MERCURY	ND, <3.7	ND, <5.2	ND, <4.3	ND, <5.3	ND, <6.6	ND, <9.3	ND, <13.2	ND, <17.4	ND, <24.6	ND, <28.0
NICKEL	ND, <91.8	ND, <128.8	ND, <106.8	ND, <132.4	ND, <164.0	ND, <232.6	ND, <330.3	ND, <434.5	ND, <614.4	ND, <698.8
SELENIUM	ND, <91.8	ND, <128.8	ND, <106.8	ND, <132.4	ND, <164.0	ND, <232.6	ND, <330.3	ND, <434.5	ND, <614.4	ND, <698.8

HIGH-SULFUR NONROAD DIESEL

METAL PM EMISSIONS, mg/hr										
COMPOUND NAME	Notch idle	Notch DB	Notch 1.00	Notch 2.00	Notch 3.00	Notch 4.00	Notch 5.00	Notch 6.00	Notch 7.00	Notch 8.00
ANTIMONY	ND, <83.6	ND, <124.4	ND, <98.4	ND, <111.2	ND, <215.1	ND, <282.7	ND, <311.4	ND, <409.4	ND, <551.8	ND, <747.0
ARSENIC	ND, <83.6	ND, <124.4	ND, <98.4	ND, <111.2	ND, <215.1	ND, <282.7	ND, <311.4	ND, <409.4	ND, <551.8	ND, <747.0
BERYLLIUM	ND, <16.7	ND, <24.9	ND, <19.7	ND, <22.2	ND, <43.0	ND, <56.5	ND, <62.3	ND, <81.9	ND, <110.4	ND, <149.4
CADMIUM	ND, <16.7	ND, <24.9	ND, <19.7	ND, <22.2	ND, <43.0	ND, <56.5	ND, <62.3	ND, <81.9	ND, <110.4	ND, <149.4
CHROMIUM	TRACE	94.05	62.01	110.06	221.10	ND, <56.5	274.66	474.93	507.66	856.07
COBALT	ND, <16.7	ND, <24.9	ND, <19.7	ND, <22.2	ND, <43.0	ND, <56.5	ND, <62.3	ND, <81.9	ND, <110.4	ND, <149.4
COPPER	ND, <16.7	ND, <24.9	ND, <19.7	ND, <22.2	ND, <43.0	ND, <56.5	ND, <62.3	ND, <81.9	ND, <110.4	ND, <149.4
LEAD	ND, <50.1	ND, <74.6	ND, <59.1	ND, <66.7	ND, <129.0	ND, <169.6	ND, <186.8	ND, <245.7	ND, <331.1	ND, <448.2
MANGANESE	ND, <16.7	ND, <24.9	ND, <19.7	ND, <22.2	ND, <43.0	ND, <56.5	ND, <62.3	ND, <81.9	ND, <110.4	ND, <149.4
MERCURY	ND, <3.3	ND, <5.0	ND, <3.9	ND, <4.4	ND, <8.6	ND, <11.3	ND, <12.5	ND, <16.4	ND, <22.1	ND, <29.9
NICKEL	ND, <83.6	ND, <124.4	ND, <98.4	ND, <111.2	ND, <215.1	ND, <282.7	ND, <311.4	ND, <409.4	ND, <551.8	ND, <747.0
SELENIUM	ND, <83.6	ND, <124.4	ND, <98.4	ND, <111.2	ND, <215.1	ND, <282.7	ND, <311.4	ND, <409.4	ND, <551.8	ND, <747.0

APPENDIX K-2: LOCOMOTIVE BN9754

CARB Diesel

METAL PM EMISSIONS , mg/hr										
COMPOUND NAME	Notch idle	Notch DB	Notch 1.00	Notch 2.00	Notch 3.00	Notch 4.00	Notch 5.00	Notch 6.00	Notch 7.00	Notch 8.00
ANTIMONY	ND, <59.3	ND, <80.6	ND, <66.4	ND, <108.3	ND, <166.7	ND, <296.4	ND, <348.0	ND, <574.0	ND, <730.2	ND, <794.4
ARSENIC	ND, <59.3	ND, <80.6	ND, <66.4	ND, <108.3	ND, <166.7	ND, <296.4	ND, <348.0	ND, <574.0	ND, <730.2	ND, <794.4
BERYLLIUM	ND, <11.9	ND, <16.1	ND, <13.3	ND, <21.7	ND, <33.3	ND, <59.3	ND, <69.6	ND, <114.8	ND, <146.0	ND, <158.9
CADMIUM	ND, <11.9	ND, <16.1	ND, <13.3	ND, <21.7	ND, <33.3	ND, <59.3	ND, <69.6	ND, <114.8	ND, <146.0	ND, <158.9
CHROMIUM	52.19	68.98	63.49	93.77	135.04	TRACE	TRACE	542.97	553.52	732.45
COBALT	ND, <11.9	ND, <16.1	ND, <13.3	ND, <21.7	ND, <33.3	ND, <59.3	ND, <69.6	ND, <114.8	ND, <146.0	ND, <158.9
COPPER	ND, <11.9	ND, <16.1	ND, <13.3	ND, <21.7	ND, <33.3	ND, <59.3	ND, <69.6	ND, <114.8	ND, <146.0	ND, <158.9
LEAD	ND, <35.6	ND, <48.4	ND, <39.8	ND, <65.0	ND, <100.0	ND, <177.8	ND, <208.8	ND, <344.4	ND, <438.1	ND, <476.6
MANGANESE	ND, <11.9	ND, <16.1	ND, <13.3	ND, <21.7	ND, <33.3	ND, <59.3	ND, <69.6	ND, <114.8	ND, <146.0	ND, <158.9
MERCURY	ND, <2.4	ND, <3.2	ND, <2.7	ND, <4.3	ND, <6.7	ND, <11.9	ND, <13.9	ND, <23.0	ND, <29.2	ND, <31.8
NICKEL	ND, <59.3	ND, <80.6	ND, <66.4	ND, <108.3	ND, <166.7	ND, <296.4	ND, <348.0	ND, <574.0	ND, <730.2	ND, <794.4
SELENIUM	ND, <59.3	ND, <80.6	ND, <66.4	ND, <108.3	ND, <166.7	ND, <296.4	ND, <348.0	ND, <574.0	ND, <730.2	ND, <794.4

ON-HIGHWAY DIESEL

METAL PM EMISSIONS , mg/hr										
COMPOUND NAME	Notch idle	Notch DB	Notch 1.00	Notch 2.00	Notch 3.00	Notch 4.00	Notch 5.00	Notch 6.00	Notch 7.00	Notch 8.00
ANTIMONY	ND, <90.6	ND, <60.6	ND, <78.5	ND, <141.8	ND, <181.7	ND, <203.1	ND, <328.7	ND, <435.0	ND, <466.4	ND, <290.3
ARSENIC	ND, <90.6	ND, <60.6	ND, <78.5	ND, <141.8	ND, <181.7	ND, <203.1	ND, <328.7	ND, <435.0	ND, <466.4	ND, <290.3
BERYLLIUM	ND, <18.1	ND, <12.1	ND, <15.7	ND, <28.4	ND, <36.3	ND, <40.6	ND, <65.7	ND, <87.0	ND, <93.3	ND, <58.1
CADMIUM	ND, <18.1	ND, <12.1	ND, <15.7	ND, <28.4	ND, <36.3	ND, <40.6	ND, <65.7	ND, <87.0	ND, <93.3	ND, <58.1
CHROMIUM	71.41	47.48	49.92	TRACE	202.03	172.20	301.07	452.37	373.09	263.62
COBALT	ND, <18.1	ND, <12.1	ND, <15.7	ND, <28.4	ND, <36.3	ND, <40.6	ND, <65.7	ND, <87.0	ND, <93.3	ND, <58.1
COPPER	ND, <18.1	ND, <12.1	ND, <15.7	ND, <28.4	ND, <36.3	ND, <40.6	ND, <65.7	ND, <87.0	ND, <93.3	ND, <58.1
LEAD	ND, <54.4	ND, <36.3	ND, <47.1	ND, <85.1	ND, <109.0	ND, <121.8	ND, <197.2	ND, <261.0	ND, <279.8	ND, <174.2
MANGANESE	ND, <18.1	ND, <12.1	ND, <15.7	ND, <28.4	ND, <36.3	ND, <40.6	ND, <65.7	ND, <87.0	ND, <93.3	ND, <58.1
MERCURY	ND, <3.6	ND, <2.4	ND, <3.1	ND, <5.7	ND, <7.3	ND, <8.1	ND, <13.1	ND, <17.4	ND, <18.7	ND, <11.6
NICKEL	ND, <90.6	ND, <60.6	ND, <78.5	ND, <141.8	ND, <181.7	ND, <203.1	ND, <328.7	ND, <435.0	ND, <466.4	ND, <290.3
SELENIUM	ND, <90.6	ND, <60.6	ND, <78.5	ND, <141.8	ND, <181.7	ND, <203.1	ND, <328.7	ND, <435.0	ND, <466.4	ND, <290.3

HIGH-SULFUR NONROAD DIESEL

METAL PM EMISSIONS , mg/hr										
COMPOUND NAME	Notch idle	Notch DB	Notch 1.00	Notch 2.00	Notch 3.00	Notch 4.00	Notch 5.00	Notch 6.00	Notch 7.00	Notch 8.00
ANTIMONY	ND, <71.1	ND, <104.9	ND, <74.6	ND, <116.5	ND, <238.1	ND, <359.0	ND, <347.3	ND, <416.7	ND, <647.7	ND, <638.7
ARSENIC	ND, <71.1	ND, <104.9	ND, <74.6	ND, <116.5	ND, <238.1	ND, <359.0	ND, <347.3	ND, <416.7	ND, <647.7	ND, <638.7
BERYLLIUM	ND, <14.2	ND, <21.0	ND, <14.9	ND, <23.3	ND, <47.6	ND, <71.8	ND, <69.5	ND, <83.3	ND, <129.5	ND, <127.7
CADMIUM	ND, <14.2	ND, <21.0	ND, <14.9	ND, <23.3	ND, <47.6	ND, <71.8	ND, <69.5	ND, <83.3	ND, <129.5	ND, <127.7
CHROMIUM	67.80	107.46	73.86	102.79	243.80	284.32	384.78	415.05	719.00	786.83
COBALT	ND, <14.2	ND, <21.0	ND, <14.9	ND, <23.3	ND, <47.6	ND, <71.8	ND, <69.5	ND, <83.3	ND, <129.5	ND, <127.7
COPPER	ND, <14.2	ND, <21.0	ND, <14.9	ND, <23.3	ND, <47.6	ND, <71.8	ND, <69.5	ND, <83.3	ND, <129.5	ND, <127.7
LEAD	ND, <42.6	ND, <63.0	ND, <44.8	ND, <69.9	ND, <142.9	ND, <215.4	ND, <208.4	ND, <250.0	ND, <388.6	ND, <383.2
MANGANESE	ND, <14.2	ND, <21.0	ND, <14.9	ND, <23.3	ND, <47.6	ND, <71.8	ND, <69.5	ND, <83.3	ND, <129.5	ND, <127.7
MERCURY	ND, <2.8	ND, <4.2	ND, <3.0	ND, <4.7	ND, <9.5	ND, <14.4	ND, <13.9	ND, <16.7	ND, <25.9	ND, <25.5
NICKEL	ND, <71.1	ND, <104.9	ND, <74.6	ND, <116.5	ND, <238.1	ND, <359.0	ND, <347.3	ND, <416.7	ND, <647.7	ND, <638.7
SELENIUM	ND, <71.1	ND, <104.9	ND, <74.6	ND, <116.5	ND, <238.1	ND, <359.0	ND, <347.3	ND, <416.7	ND, <647.7	ND, <638.7

APPENDIX K-3: LOCOMOTIVE UP9715

CARB Diesel

METAL PM EMISSIONS , mg/hr											
COMPOUND NAME	Notch low idle	Notch idle	Notch DB	Notch 1.00	Notch 2.00	Notch 3.00	Notch 4.00	Notch 5.00	Notch 6.00	Notch 7.00	Notch 8.00
ANTIMONY	ND, <27.1	ND, <28.2	ND, <41.0	ND, <40.3	ND, <81.3	ND, <156.0	ND, <331.9	ND, <446.9	ND, <577.2	ND, <712.4	ND, <790.6
ARSENIC	ND, <27.1	ND, <28.2	ND, <41.0	ND, <40.3	ND, <81.3	ND, <156.0	ND, <331.9	ND, <446.9	ND, <577.2	ND, <712.4	ND, <790.6
BERYLLIUM	ND, <5.4	ND, <5.6	ND, <8.2	ND, <8.1	ND, <16.3	ND, <31.2	ND, <66.4	ND, <89.4	ND, <115.4	ND, <142.5	ND, <158.1
CADMIUM	ND, <5.4	ND, <5.6	ND, <8.2	ND, <8.1	ND, <16.3	ND, <31.2	ND, <66.4	ND, <89.4	ND, <115.4	ND, <142.5	ND, <158.1
CHROMIUM	38.26	25.50	59.80	41.12	81.61	165.99	TRACE	342.31	709.94	579.91	845.90
COBALT	ND, <5.4	ND, <5.6	ND, <8.2	ND, <8.1	ND, <16.3	ND, <31.2	ND, <66.4	ND, <89.4	ND, <115.4	ND, <142.5	ND, <158.1
COPPER	ND, <5.4	ND, <5.6	ND, <8.2	ND, <8.1	ND, <16.3	ND, <31.2	ND, <66.4	ND, <89.4	ND, <115.4	ND, <142.5	ND, <158.1
LEAD	ND, <16.3	ND, <16.9	ND, <24.6	ND, <24.2	ND, <48.8	ND, <93.6	ND, <199.2	ND, <268.1	ND, <346.3	ND, <427.4	ND, <474.3
MANGANESE	ND, <5.4	ND, <5.6	ND, <8.2	ND, <8.1	ND, <16.3	ND, <31.2	ND, <66.4	ND, <89.4	ND, <115.4	ND, <142.5	ND, <158.1
MERCURY	ND, <1.1	ND, <1.1	ND, <1.6	ND, <1.6	ND, <3.3	ND, <6.2	ND, <13.3	ND, <17.9	ND, <23.1	ND, <28.5	ND, <31.6
NICKEL	ND, <27.1	ND, <28.2	ND, <41.0	ND, <40.3	ND, <81.3	ND, <156.0	ND, <331.9	ND, <446.9	ND, <577.2	ND, <712.4	ND, <790.6
SELENIUM	ND, <27.1	ND, <28.2	ND, <41.0	ND, <40.3	ND, <81.3	ND, <156.0	ND, <331.9	ND, <446.9	ND, <577.2	ND, <712.4	ND, <790.6

ON-HIGHWAY DIESEL

METAL PM EMISSIONS , mg/hr											
COMPOUND NAME	Notch low idle	Notch idle	Notch DB	Notch 1.00	Notch 2.00	Notch 3.00	Notch 4.00	Notch 5.00	Notch 6.00	Notch 7.00	Notch 8.00
ANTIMONY	ND, <24.2	ND, <7.5	ND, <26.3	ND, <32.5	ND, <81.3	ND, <189.8	ND, <277.5	ND, <435.7	ND, <587.3	ND, <680.3	ND, <942.3
ARSENIC	ND, <24.2	ND, <7.5	ND, <26.3	ND, <32.5	ND, <81.3	ND, <189.8	ND, <277.5	ND, <435.7	ND, <587.3	ND, <680.3	ND, <942.3
BERYLLIUM	ND, <4.8	ND, <1.5	ND, <5.3	ND, <6.5	ND, <16.3	ND, <38.0	ND, <55.5	ND, <87.1	ND, <117.5	ND, <136.1	ND, <188.5
CADMIUM	ND, <4.8	ND, <1.5	ND, <5.3	ND, <6.5	ND, <16.3	ND, <38.0	ND, <55.5	ND, <87.1	ND, <117.5	ND, <136.1	ND, <188.5
CHROMIUM	31.36	7.62	28.30	41.53	82.13	TRACE	TRACE	350.30	642.50	715.64	855.62
COBALT	ND, <4.8	ND, <1.5	ND, <5.3	ND, <6.5	ND, <16.3	ND, <38.0	ND, <55.5	ND, <87.1	ND, <117.5	ND, <136.1	ND, <188.5
COPPER	ND, <4.8	ND, <1.5	ND, <5.3	ND, <6.5	ND, <16.3	ND, <38.0	ND, <55.5	ND, <87.1	ND, <117.5	ND, <136.1	ND, <188.5
LEAD	ND, <14.5	ND, <4.5	ND, <15.8	ND, <19.5	ND, <48.8	ND, <113.9	ND, <166.5	ND, <261.4	ND, <352.4	ND, <408.2	ND, <565.4
MANGANESE	ND, <4.8	ND, <1.5	ND, <5.3	ND, <6.5	ND, <16.3	ND, <38.0	ND, <55.5	ND, <87.1	ND, <117.5	ND, <136.1	ND, <188.5
MERCURY	ND, <1.0	ND, <0.3	ND, <1.1	ND, <1.3	ND, <3.3	ND, <7.6	ND, <11.1	ND, <17.4	ND, <23.5	ND, <27.2	ND, <37.7
NICKEL	ND, <24.2	ND, <7.5	ND, <26.3	ND, <32.5	ND, <81.3	ND, <189.8	ND, <277.5	ND, <435.7	ND, <587.3	ND, <680.3	ND, <942.3
SELENIUM	ND, <24.2	ND, <7.5	ND, <26.3	ND, <32.5	ND, <81.3	ND, <189.8	ND, <277.5	ND, <435.7	ND, <587.3	ND, <680.3	ND, <942.3

HIGH-SULFUR NONROAD DIESEL

METAL PM EMISSIONS , mg/hr											
COMPOUND NAME	Notch low idle	Notch idle	Notch DB	Notch 1.00	Notch 2.00	Notch 3.00	Notch 4.00	Notch 5.00	Notch 6.00	Notch 7.00	Notch 8.00
ANTIMONY	ND, <26.7	ND, <24.1	ND, <42.6	ND, <25.8	ND, <61.5	ND, <151.3	ND, <113.0	ND, <363.9	ND, <441.5	ND, <570.3	ND, <704.8
ARSENIC	ND, <26.7	ND, <24.1	ND, <42.6	ND, <25.8	ND, <61.5	ND, <151.3	ND, <113.0	ND, <363.9	ND, <441.5	ND, <570.3	ND, <704.8
BERYLLIUM	ND, <5.3	ND, <4.8	ND, <8.5	ND, <5.2	ND, <12.3	ND, <30.3	ND, <22.6	ND, <72.8	ND, <88.3	ND, <114.1	ND, <141.0
CADMIUM	ND, <5.3	ND, <4.8	ND, <8.5	ND, <5.2	ND, <12.3	ND, <30.3	ND, <22.6	ND, <72.8	ND, <88.3	ND, <114.1	ND, <141.0
CHROMIUM	32.88	41.88	55.19	22.87	120.59	235.35	147.83	547.27	703.70	691.21	933.09
COBALT	ND, <5.3	ND, <4.8	ND, <8.5	ND, <5.2	ND, <12.3	ND, <30.3	ND, <22.6	ND, <72.8	ND, <88.3	ND, <114.1	ND, <141.0
COPPER	ND, <5.3	ND, <4.8	ND, <8.5	ND, <5.2	ND, <12.3	ND, <30.3	ND, <22.6	ND, <72.8	ND, <88.3	ND, <114.1	ND, <141.0
LEAD	ND, <16.0	ND, <14.5	ND, <25.6	ND, <15.5	ND, <36.9	ND, <90.8	ND, <67.8	ND, <218.3	ND, <264.9	ND, <342.2	ND, <422.9
MANGANESE	ND, <5.3	ND, <4.8	ND, <8.5	ND, <5.2	ND, <12.3	ND, <30.3	ND, <22.6	ND, <72.8	ND, <88.3	ND, <114.1	ND, <141.0
MERCURY	ND, <1.1	ND, <1.0	ND, <1.7	ND, <1.0	ND, <2.5	ND, <6.1	ND, <4.5	ND, <14.6	ND, <17.7	ND, <22.8	ND, <28.2
NICKEL	ND, <26.7	ND, <24.1	ND, <42.6	ND, <25.8	ND, <61.5	ND, <151.3	ND, <113.0	ND, <363.9	ND, <441.5	ND, <570.3	ND, <704.8
SELENIUM	ND, <26.7	ND, <24.1	ND, <42.6	ND, <25.8	ND, <61.5	ND, <151.3	ND, <113.0	ND, <363.9	ND, <441.5	ND, <570.3	ND, <704.8

APPENDIX K-4: LOCOMOTIVE UP9724

CARB Diesel

METAL PM EMISSIONS , mg/hr

COMPOUND NAME	Notch low idle	Notch idle	Notch DB	Notch 1.00	Notch 2.00	Notch 3.00	Notch 4.00	Notch 5.00	Notch 6.00	Notch 7.00	Notch 8.00
ANTIMONY	ND, <32.7	ND, <38.3	ND, <20.6	ND, <40.3	ND, <83.4	ND, <187.1	ND, <274.4	ND, <427.0	ND, <478.0	ND, <731.6	ND, <924.0
ARSENIC	ND, <32.7	ND, <38.3	ND, <20.6	ND, <40.3	ND, <83.4	ND, <187.1	ND, <274.4	ND, <427.0	ND, <478.0	ND, <731.6	ND, <924.0
BERYLLIUM	ND, <6.5	ND, <7.7	ND, <4.1	ND, <8.1	ND, <16.7	ND, <37.4	ND, <54.9	ND, <85.4	ND, <95.6	ND, <146.3	ND, <184.8
CADMIUM	ND, <6.5	ND, <7.7	ND, <4.1	ND, <8.1	ND, <16.7	ND, <37.4	ND, <54.9	ND, <85.4	ND, <95.6	ND, <146.3	ND, <184.8
CHROMIUM	26.17	TRACE	17.05	30.38	63.92	135.06	266.75	455.18	490.39	733.09	TRACE
COBALT	ND, <6.5	ND, <7.7	ND, <4.1	ND, <8.1	ND, <16.7	ND, <37.4	ND, <54.9	ND, <85.4	ND, <95.6	ND, <146.3	ND, <184.8
COPPER	ND, <6.5	ND, <7.7	ND, <4.1	ND, <8.1	ND, <16.7	ND, <37.4	ND, <54.9	ND, <85.4	ND, <95.6	ND, <146.3	ND, <184.8
LEAD	ND, <19.6	ND, <23.0	ND, <12.4	ND, <24.2	ND, <50.1	ND, <112.2	ND, <164.7	ND, <256.2	ND, <286.8	ND, <439.0	ND, <554.4
MANGANESE	ND, <6.5	ND, <7.7	ND, <4.1	ND, <8.1	ND, <16.7	ND, <37.4	ND, <54.9	ND, <85.4	ND, <95.6	ND, <146.3	ND, <184.8
MERCURY	ND, <1.3	ND, <1.5	ND, <0.8	ND, <1.6	ND, <3.3	ND, <7.5	ND, <11.0	ND, <17.1	ND, <19.1	ND, <29.3	ND, <37.0
NICKEL	ND, <32.7	ND, <38.3	ND, <20.6	ND, <40.3	ND, <83.4	ND, <187.1	ND, <274.4	ND, <427.0	ND, <478.0	ND, <731.6	ND, <924.0
SELENIUM	ND, <32.7	ND, <38.3	ND, <20.6	ND, <40.3	ND, <83.4	ND, <187.1	ND, <274.4	ND, <427.0	ND, <478.0	ND, <731.6	ND, <924.0

ON-HIGHWAY DIESEL

METAL PM EMISSIONS , mg/hr

COMPOUND NAME	Notch low idle	Notch idle	Notch DB	Notch 1.00	Notch 2.00	Notch 3.00	Notch 4.00	Notch 5.00	Notch 6.00	Notch 7.00	Notch 8.00
ANTIMONY	ND, <31.8	ND, <11.2	ND, <49.8	ND, <29.1	ND, <75.2	ND, <202.2	ND, <276.8	ND, <453.1	ND, <542.8	ND, <714.6	ND, <917.2
ARSENIC	ND, <31.8	ND, <11.2	ND, <49.8	ND, <29.1	ND, <75.2	ND, <202.2	ND, <276.8	ND, <453.1	ND, <542.8	ND, <714.6	ND, <917.2
BERYLLIUM	ND, <6.4	ND, <2.2	ND, <10.0	ND, <5.8	ND, <15.0	ND, <40.4	ND, <55.4	ND, <90.6	ND, <108.6	ND, <142.9	ND, <183.4
CADMIUM	ND, <6.4	ND, <2.2	ND, <10.0	ND, <5.8	ND, <15.0	ND, <40.4	ND, <55.4	ND, <90.6	ND, <108.6	ND, <142.9	ND, <183.4
CHROMIUM	42.32	11.34	62.14	28.48	75.69	222.81	306.10	370.62	526.54	TRACE	781.45
COBALT	ND, <6.4	ND, <2.2	ND, <10.0	ND, <5.8	ND, <15.0	ND, <40.4	ND, <55.4	ND, <90.6	ND, <108.6	ND, <142.9	ND, <183.4
COPPER	ND, <6.4	ND, <2.2	ND, <10.0	ND, <5.8	ND, <15.0	ND, <40.4	ND, <55.4	ND, <90.6	ND, <108.6	ND, <142.9	ND, <183.4
LEAD	ND, <19.1	ND, <6.7	ND, <29.9	ND, <17.5	ND, <45.1	ND, <121.3	ND, <166.1	ND, <271.9	ND, <325.7	ND, <428.7	ND, <550.3
MANGANESE	ND, <6.4	ND, <2.2	ND, <10.0	ND, <5.8	ND, <15.0	ND, <40.4	ND, <55.4	ND, <90.6	ND, <108.6	ND, <142.9	ND, <183.4
MERCURY	ND, <1.3	ND, <0.4	ND, <2.0	ND, <1.2	ND, <3.0	ND, <8.1	ND, <11.1	ND, <18.1	ND, <21.7	ND, <28.6	ND, <36.7
NICKEL	ND, <31.8	ND, <11.2	ND, <49.8	ND, <29.1	ND, <75.2	ND, <202.2	ND, <276.8	ND, <453.1	ND, <542.8	ND, <714.6	ND, <917.2
SELENIUM	ND, <31.8	ND, <11.2	ND, <49.8	ND, <29.1	ND, <75.2	ND, <202.2	ND, <276.8	ND, <453.1	ND, <542.8	ND, <714.6	ND, <917.2

HIGH-SULFUR NONROAD DIESEL

METAL PM EMISSIONS , mg/hr

COMPOUND NAME	Notch low idle	Notch idle	Notch DB	Notch 1.00	Notch 2.00	Notch 3.00	Notch 4.00	Notch 5.00	Notch 6.00	Notch 7.00	Notch 8.00
ANTIMONY	ND, <25.0	ND, <46.5	ND, <56.0	ND, <28.9	ND, <88.0	ND, <191.3	ND, <262.6	ND, <446.8	ND, <335.3	ND, <696.3	ND, <975.2
ARSENIC	ND, <25.0	ND, <46.5	ND, <56.0	ND, <28.9	ND, <88.0	ND, <191.3	ND, <262.6	ND, <446.8	ND, <335.3	ND, <696.3	ND, <975.2
BERYLLIUM	ND, <5.0	ND, <9.3	ND, <11.2	ND, <5.8	ND, <17.6	ND, <38.3	ND, <52.5	ND, <89.4	ND, <67.1	ND, <139.3	ND, <195.0
CADMIUM	ND, <5.0	ND, <9.3	ND, <11.2	ND, <5.8	ND, <17.6	ND, <38.3	ND, <52.5	ND, <89.4	ND, <67.1	ND, <139.3	ND, <195.0
CHROMIUM	24.77	48.59	113.13	21.52	91.73	200.06	228.44	393.19	667.15	474.89	1094.16
COBALT	ND, <5.0	ND, <9.3	ND, <11.2	ND, <5.8	ND, <17.6	ND, <38.3	ND, <52.5	ND, <89.4	ND, <67.1	ND, <139.3	ND, <195.0
COPPER	ND, <5.0	ND, <9.3	ND, <11.2	ND, <5.8	ND, <17.6	ND, <38.3	ND, <52.5	ND, <89.4	ND, <67.1	ND, <139.3	ND, <195.0
LEAD	ND, <15.0	ND, <27.9	ND, <33.6	ND, <17.4	ND, <52.8	ND, <114.8	ND, <157.5	ND, <268.1	ND, <201.2	ND, <417.8	ND, <585.1
MANGANESE	ND, <5.0	ND, <9.3	ND, <11.2	ND, <5.8	ND, <17.6	ND, <38.3	ND, <52.5	ND, <89.4	ND, <67.1	ND, <139.3	ND, <195.0
MERCURY	ND, <1.0	ND, <1.9	ND, <2.2	ND, <1.2	ND, <3.5	ND, <7.7	ND, <10.5	ND, <17.9	ND, <13.4	ND, <27.9	ND, <39.0
NICKEL	ND, <25.0	ND, <46.5	ND, <56.0	ND, <28.9	ND, <88.0	ND, <191.3	ND, <262.6	ND, <446.8	ND, <335.3	ND, <696.3	ND, <975.2
SELENIUM	ND, <25.0	ND, <46.5	ND, <56.0	ND, <28.9	ND, <88.0	ND, <191.3	ND, <262.6	ND, <446.8	ND, <335.3	ND, <696.3	ND, <975.2

APPENDIX L

Sulfate Data

APPENDIX L-1: EMD SULFATE EMISSIONS SUMMARY

BNSF 9693

	CARB diesel (EM-2663-F)							On-Hwy Diesel (EM-2677-F)							High Sulfur, Nonroad diesel (EM-2664-F)						
TEST NO.	Total Part., g/hp-hr	Total Part., g/hr	Total Part., g/lb fuel	SO4, mg/hp-hr	SO4, mg/hr	SO4, mg/lb fuel	% Sulfate Conversion	Total Part., g/hp-hr	Total Part., g/hr	Total Part., g/lb fuel	SO4, mg/hp-hr	SO4, mg/hr	SO4, mg/lb fuel	% Sulfate Conversion	Total Part., g/hp-hr	Total Part. g/hr	Total Part., g/lb fuel	SO4, mg/hp-hr	SO4, mg/hr	SO4, mg/lb fuel	% Sulfate Conversion
DB-2	2.592	50	1.066	85.82	1,656	35.30	51.8	2.504	48	1.000	28.21	541	11.27	2.5	2.831	55	1.158	100.90	1,960	41.27	0.6
Idle	1.355	18	0.735	56.82	755	30.81	45.2	3.125	42	1.615	23.75	319	12.28	2.7	1.290	17	0.675	70.38	928	36.81	0.6
Notch 1	0.317	65	0.717	6.51	1,334	14.72	21.6	0.276	57	0.621	2.16	446	4.85	1.1	0.243	50	0.538	10.60	2,182	23.46	0.4
Notch 2	0.259	113	0.663	6.91	3,015	17.69	26.0	0.228	100	0.580	1.13	495	2.87	0.6	0.228	100	0.575	18.23	7,994	45.94	0.7
Notch 3	0.282	277	0.781	7.78	7,644	21.56	31.7	0.221	217	0.605	1.94	1,906	5.32	1.2	0.293	287	0.795	22.21	21,755	60.26	0.9
Notch 4	0.270	409	0.762	7.59	11,495	21.41	31.4	0.239	363	0.669	1.95	2,955	5.45	1.2	0.300	456	0.839	35.62	54,149	99.61	1.5
Notch 5	0.271	543	0.769	5.26	10,534	14.91	21.9	0.261	525	0.738	2.84	5,707	8.02	1.8	0.327	657	0.921	40.18	80,736	113.19	1.7
Notch 6	0.291	837	0.838	4.36	12,550	12.57	18.5	0.350	1011	1.004	3.50	10,121	10.05	2.2	0.396	1141	1.137	32.58	93,862	93.56	1.4
Notch 7	0.287	1050	0.863	4.29	15,685	12.89	18.9	0.300	1094	0.893	5.31	19,372	15.81	3.5	0.404	1478	1.210	25.14	91,962	75.29	1.2
Notch 8	0.481	2024	1.454	2.57	10,796	7.75	11.4	0.493	2074	1.478	3.77	15,879	11.32	2.5	0.587	2469	1.764	22.73	95,600	68.29	1.1

BNSF 9754

	CARB diesel (EM-2663-F)							On-Hwy Diesel (EM-2677-F)							High Sulfur, Nonroad diesel (EM-2664-F)						
TEST NO.	Total Part., g/hp-hr	Total Part., g/hr	Total Part., g/lb fuel	SO4, mg/hp-hr	SO4, mg/hr	SO4, mg/lb fuel	% Sulfate Conversion	Total Part., g/hp-hr	Total Part., g/hr	Total Part., g/lb fuel	SO4, mg/hp-hr	SO4, mg/hr	SO4, mg/lb fuel	% Sulfate Conversion	Total Part., g/hp-hr	Total Part. g/hr	Total Part., g/lb fuel	SO4, mg/hp-hr	SO4, mg/hr	SO4, mg/lb fuel	% Sulfate Conversion
DB-2	3.457	67	1.373	74.50	1,444	29.59	43.4	2.386	46	0.966	30.81	594	12.48	2.8	3.030	59	1.216	141.19	2,749	56.68	0.9
Idle	1.299	18	0.672	15.76	218	8.15	12.0	1.542	21	0.772	32.54	443	16.29	3.6	1.795	24	0.870	130.37	1,743	63.16	1.0
Notch 1	0.444	91	0.998	3.52	721	7.90	11.6	0.325	66	0.712	2.83	575	6.20	1.4	0.468	96	1.032	23.10	4,739	50.96	0.8
Notch 2	0.305	134	0.789	0.79	349	2.05	3.0	0.293	128	0.749	1.73	755	4.41	1.0	0.355	156	0.901	24.03	10,558	60.96	0.9
Notch 3	0.393	385	1.096	0.91	889	2.53	3.7	0.362	354	1.002	2.20	2,151	6.09	1.4	0.262	256	0.718	33.52	32,750	91.81	1.4
Notch 4	0.310	469	0.891	1.04	1,570	2.98	4.4	0.309	468	0.882	2.68	4,062	7.66	1.7	0.400	605	1.127	40.22	60,831	113.34	1.7
Notch 5	0.300	601	0.874	1.56	3,129	4.55	6.7	0.280	562	0.812	3.08	6,173	8.92	2.0	0.368	738	1.054	32.89	65,965	94.18	1.5
Notch 6	0.353	1017	1.054	2.64	7,603	7.88	11.6	0.339	977	1.010	6.19	17,828	18.42	4.1	0.438	1263	1.291	29.12	83,958	85.79	1.3
Notch 7	0.366	1337	1.133	3.89	14,220	12.05	17.7	0.368	1346	1.131	2.64	9,655	8.11	1.8	0.425	1556	1.299	30.75	112,582	94.01	1.5
Notch 8	0.378	1591	1.175	3.22	13,547	10.01	14.7	0.392	1652	1.214	3.43	14,461	10.62	2.4	0.432	1819	1.328	25.28	106,432	77.69	1.2

BNSF 9696

	CARB diesel (EM-2663-F)							On-Hwy Diesel (EM-2677-F)							High Sulfur, Nonroad diesel (EM-2664-F)						
TEST NO.	Total Part., g/hp-hr	Total Part., g/hr	Total Part., g/lb fuel	SO4, mg/hp-hr	SO4, mg/hr	SO4, mg/lb fuel	% Sulfate Conversion	Total Part., g/hp-hr	Total Part., g/hr	Total Part., g/lb fuel	SO4, mg/hp-hr	SO4, mg/hr	SO4, mg/lb fuel	% Sulfate Conversion	Total Part., g/hp-hr	Total Part. g/hr	Total Part., g/lb fuel	SO4, mg/hp-hr	SO4, mg/hr	SO4, mg/lb fuel	% Sulfate Conversion
DB-2	1.933	37	0.781	19.93	381	8.05	11.8	2.418	46	0.996	77.27	1,470	31.82	7.1	2.337	44	0.917	150.79	2,839	59.14	0.9
Idle	0.980	13	0.510	10.35	137	5.39	7.9	1.087	15	0.566	17.18	237	8.94	2.0	1.399	19	0.731	117.60	1,597	61.43	0.9
Notch 1	0.205	42	0.462	1.08	222	2.44	3.6	0.243	50	0.543	2.55	524	5.70	1.3	0.208	43	0.473	16.78	3,469	38.12	0.6
Notch 2	0.211	92	0.544	0.85	369	2.18	3.2	0.249	109	0.641	1.27	557	3.27	0.7	0.240	105	0.607	24.18	10,577	61.14	0.9
Notch 3	0.234	229	0.645	0.75	730	2.06	3.0	0.282	276	0.771	1.71	1,676	4.68	1.0	0.276	270	0.748	35.30	34,534	95.66	1.5
Notch 4	0.245	372	0.691	0.87	1,328	2.47	3.6	0.261	396	0.733	2.55	3,876	7.18	1.6	0.350	531	0.973	51.71	78,451	143.68	2.2
Notch 5	0.244	486	0.702	1.80	3,582	5.18	7.6	0.258	515	0.738	5.37	10,727	15.37	3.4	0.339	669	0.957	57.22	112,928	161.56	2.5
Notch 6	0.202	581	0.608	2.41	6,928	7.25	10.7	0.231	666	0.695	5.90	17,004	17.75	3.9	0.295	851	0.883	48.27	139,261	144.46	2.2
Notch 7	0.215	786	0.667	2.64	9,643	8.18	12.0	0.242	886	0.748	5.64	20,645	17.44	3.9	0.262	957	0.804	12.28	44,869	37.67	0.6
Notch 8	0.213	896	0.658	2.63	11,080	8.14	12.0	0.244	1026	0.749	6.65	27,970	20.42	4.5	0.297	1249	0.906	16.05	67,501	48.95	0.8

APPENDIX L-2: GE SULFATE EMISSIONS SUMMARY

UP 9715

	CARB diesel (EM-2663-F)							On-Hwy Diesel (EM-2677-F)							High Sulfur, Nonroad diesel (EM-2664-F)						
TEST NO.	Total Part., g/hp-hr	Total Part., g/hr	Total Part., g/lb fuel	SO4, mg/hp-hr	SO4, mg/hr	SO4, mg/lb fuel	% Sulfate Conversion	Total Part., g/hp-hr	Total Part., g/hr	Total Part., g/lb fuel	SO4, mg/hp-hr	SO4, mg/hr	SO4, mg/lb fuel	% Sulfate Conversion	Total Part., g/hp-hr	Total Part g/hr	Total Part., g/lb fuel	SO4, mg/hp-hr	SO4, mg/hr	SO4, mg/lb fuel	% Sulfate Conversion
DB-2	1.769	39	0.913	33.48	738	17.29	25.4	1.088	27	0.662	4.64	115	2.82	0.6	1.828	42	1.042	80.14	1,841	45.69	0.7
Low Idle	2.256	23	1.162	22.70	231	11.69	17.2	1.770	19	1.188	6.59	71	4.42	1.0	4.068	41	1.925	107.86	1,087	51.04	0.8
Idle	1.471	21	0.820	14.58	208	8.13	11.9	2.120	23	0.852	8.18	89	3.29	0.7	2.680	29	1.272	137.40	1,487	65.21	1.0
Notch 1	0.151	30	0.370	1.89	375	4.63	6.8	0.182	33	0.407	1.33	241	2.98	0.7	0.260	50	0.599	24.95	4,799	57.47	0.9
Notch 2	0.104	52	0.276	3.03	1,515	8.04	11.8	0.105	53	0.288	1.24	628	3.41	0.8	0.212	105	0.565	46.48	23,019	123.76	1.9
Notch 3	0.196	203	0.521	12.57	13,021	33.44	49.1	0.144	149	0.379	2.02	2,091	5.32	1.2	0.283	289	0.733	67.17	68,594	173.96	2.7
Notch 4	0.183	283	0.498	10.52	16,262	28.63	42.0	0.157	243	0.423	4.50	6,962	12.12	2.7	0.260	399	0.698	54.99	84,388	147.66	2.3
Notch 5	0.171	380	0.479	9.32	20,708	26.12	38.4	0.147	331	0.410	4.85	10,917	13.53	3.0	0.241	537	0.671	47.93	106,809	133.44	2.1
Notch 6	0.124	363	0.361	5.94	17,396	17.31	25.4	0.121	355	0.348	3.43	10,068	9.86	2.2	0.217	638	0.626	44.40	130,544	128.05	2.0
Notch 7	0.091	334	0.270	3.61	13,261	10.73	15.8	0.106	390	0.310	3.41	12,561	10.00	2.2	0.203	744	0.594	45.45	166,589	132.97	2.1
Notch 8	0.105	473	0.307	2.43	10,964	7.12	10.5	0.117	522	0.336	3.16	14,096	9.07	2.0	0.226	1014	0.651	45.90	205,961	132.28	2.0

UP 9724

	CARB diesel (EM-2663-F)							On-Hwy Diesel (EM-2677-F)							High Sulfur, Nonroad diesel (EM-2664-F)						
TEST NO.	Total Part., g/hp-hr	Total Part., g/hr	Total Part., g/lb fuel	SO4, mg/hp-hr	SO4, mg/hr	SO4, mg/lb fuel	% Sulfate Conversion	Total Part., g/hp-hr	Total Part., g/hr	Total Part., g/lb fuel	SO4, mg/hp-hr	SO4, mg/hr	SO4, mg/lb fuel	% Sulfate Conversion	Total Part., g/hp-hr	Total Part g/hr	Total Part., g/lb fuel	SO4, mg/hp-hr	SO4, mg/hr	SO4, mg/lb fuel	% Sulfate Conversion
DB-2	2.247	56	1.333	13.83	345	8.21	12.1	3.435	79	1.904	23.42	539	12.98	2.9	3.855	96	1.963	91.11	2,269	46.40	0.7
Low Idle	4.266	51	2.383	26.65	319	14.89	21.9	5.245	63	2.825	21.48	258	11.57	2.6	3.617	40	2.312	93.95	1,039	60.06	0.9
Idle	3.513	42	1.500	22.99	275	9.82	14.4	3.251	39	1.444	27.30	327	12.13	2.7	3.471	42	1.556	95.14	1,151	42.64	0.7
Notch 1	0.379	75	0.911	2.23	442	5.37	7.9	0.550	108	1.295	3.77	740	8.87	2.0	0.353	70	0.846	21.49	4,261	51.52	0.8
Notch 2	0.316	157	0.840	2.85	1,416	7.58	11.1	0.418	207	1.099	6.21	3,073	16.31	3.6	0.323	160	0.829	47.43	23,495	121.67	1.9
Notch 3	0.236	245	0.627	5.82	6,040	15.46	22.7	0.241	249	0.634	8.43	8,711	22.17	4.9	0.334	345	0.860	61.46	63,479	158.18	2.4
Notch 4	0.222	343	0.607	10.25	15,837	28.01	41.1	0.196	303	0.533	9.82	15,181	26.73	5.9	0.296	458	0.791	56.84	87,954	151.93	2.3
Notch 5	0.166	369	0.473	11.63	25,844	33.13	48.7	0.141	314	0.400	8.55	19,051	24.28	5.4	0.229	509	0.637	42.86	95,265	119.26	1.8
Notch 6	0.113	332	0.336	6.11	17,961	18.20	26.7	0.106	313	0.315	4.24	12,514	12.59	2.8	0.195	575	0.569	40.48	119,369	118.07	1.8
Notch 7	0.085	312	0.258	3.32	12,193	10.08	14.8	0.092	336	0.276	3.26	11,903	9.79	2.2	0.206	754	0.614	58.70	214,853	174.99	2.7
Notch 8	0.085	382	0.255	2.49	11,203	7.48	11.0	0.087	393	0.261	2.63	11,891	7.90	1.8	0.212	956	0.628	66.97	301,998	198.51	3.1

UP 9733

	CARB diesel (EM-2663-F)							On-Hwy Diesel (EM-2677-F)							High Sulfur, Nonroad diesel (EM-2664-F)						
TEST NO.	Total Part., g/hp-hr	Total Part., g/hr	Total Part., g/lb fuel	SO4, mg/hp-hr	SO4, mg/hr	SO4, mg/lb fuel	% Sulfate Conversion	Total Part., g/hp-hr	Total Part., g/hr	Total Part., g/lb fuel	SO4, mg/hp-hr	SO4, mg/hr	SO4, mg/lb fuel	% Sulfate Conversion	Total Part., g/hp-hr	Total Part g/hr	Total Part., g/lb fuel	SO4, mg/hp-hr	SO4, mg/hr	SO4, mg/lb fuel	% Sulfate Conversion
DB-2	1.531	35	0.845	13.16	301	7.27	10.7	1.793	41	0.911	10.52	241	5.35	1.2	1.696	37	0.875	71.11	1,551	36.68	0.6
Low Idle	1.718	17	0.876	5.69	56	2.90	4.3	2.338	23	1.045	10.75	106	4.80	1.1	2.340	23	1.369	90.49	889	52.94	0.8
Idle	1.687	17	0.691	13.92	140	5.70	8.4	2.463	25	0.969	12.03	122	4.73	1.1	2.864	29	1.098	136.47	1,382	52.34	0.8
Notch 1	0.194	37	0.468	0.75	143	1.81	2.7	0.253	48	0.600	1.24	235	2.94	0.7	0.264	51	0.622	18.75	3,623	44.18	0.7
Notch 2	0.136	68	0.356	0.33	166	0.87	1.3	0.185	92	0.489	0.90	445	2.37	0.5	0.215	108	0.568	34.17	17,164	90.34	1.4
Notch 3	0.124	128	0.322	0.74	768	1.93	2.8	0.133	138	0.351	1.41	1,465	3.73	0.8	0.261	270	0.682	61.36	63,474	160.29	2.5
Notch 4	0.139	215	0.375	2.47	3,822	6.66	9.8	0.124	193	0.337	2.70	4,208	7.34	1.6	0.230	357	0.619	57.01	88,485	153.35	2.4
Notch 5	0.123	273	0.345	4.93	10,943	13.83	20.3	0.117	260	0.327	3.61	8,023	10.09	2.2	0.206	459	0.570	52.18	116,266	144.43	2.2
Notch 6	0.081	240	0.239	2.79	8,272	8.24	12.1	0.093	275	0.272	2.81	8,297	8.21	1.8	0.170	500	0.490	43.39	127,621	125.00	1.9
Notch 7	0.074	273	0.221	2.28	8,423	6.81	10.0	0.084	308	0.248	2.65	9,716	7.83	1.7	0.155	567	0.453	25.87	94,618	75.63	1.2
Notch 8	0.101	453	0.295	1.75	7,865	5.11	7.5	0.117	527	0.341	2.33	10,511	6.79	1.5	0.188	847	0.543	46.50	209,513	134.39	2.1

APPENDIX L-3: EPA LINE-HAUL DUTY-CYCLE WEIGHTED EMD SULFATE EMISSIONS SUMMARY

BNSF 9693

		CARB Diesel		On-Highway Diesel		High-Sulfur, Nonroad	
	WF	wt. bhp	wt. SO4	wt. bhp	wt. SO4	wt. bhp	wt. SO4
DB-2	31.5%	6.1	521.5	6.1	170.3	6.1	618
Idle	19.0%	2.6	143.4	2.6	60.7	2.6	176
Notch 1	6.5%	13.3	86.7	13.3	29.0	13.3	142
Notch 2	6.5%	28.4	196.0	28.5	32.2	28.5	520
Notch 3	5.2%	51.0	397.5	51.0	99.1	51.0	1,131
Notch 4	4.4%	66.8	505.8	66.9	130.0	66.9	2,383
Notch 5	3.8%	76.2	400.3	76.3	216.9	76.3	3,068
Notch 6	3.9%	112.4	489.4	112.7	394.7	112.4	3,661
Notch 7	3.0%	109.6	470.6	109.6	581.1	109.7	2,759
Notch 8	16.2%	682.2	1749.0	681.7	2572.4	681.9	15,487
	Total	**1148.6**	**4960.1**	**1148.6**	**4286.4**	**1148.4**	**29,944**
EPA Line-Haul Duty Cycle Weighted Sulfate Emissions, mg/hp-hr			**4.32**		**3.73**		**26**

BNSF 9754

		CARB Diesel		On-Highway Diesel		High-Sulfur, Nonroad	
	WF	wt. bhp	wt. SO4	wt. bhp	wt. SO4	wt. bhp	wt. SO4
DB-2	31.5%	6.1	454.83	6.0	187.08	6.1	866
Idle	19.0%	2.6	41.50	2.6	84.21	2.6	331
Notch 1	6.5%	13.3	46.85	13.3	37.36	13.3	308
Notch 2	6.5%	28.5	22.68	28.5	49.07	28.5	686
Notch 3	5.2%	50.9	46.22	50.9	111.84	50.9	1,703
Notch 4	4.4%	66.7	69.06	66.7	178.75	66.6	2,677
Notch 5	3.8%	76.2	118.89	76.2	234.56	76.2	2,507
Notch 6	3.9%	112.5	296.53	112.4	695.29	112.4	3,274
Notch 7	3.0%	109.6	426.60	109.7	289.66	109.7	3,377
Notch 8	16.2%	682.3	2194.62	682.2	2342.61	681.8	17,242
	Total	**1148.7**	**3717.8**	**1148.5**	**4210.4**	**1148.1**	**32,971**
EPA Line-Haul Duty Cycle Weighted Sulfate Emissions, mg/hp-hr			**3.24**		**3.67**		**29**

BNSF 9696

		CARB Diesel		On-Highway Diesel		High-Sulfur, Nonroad	
	WF	wt. bhp	wt. SO4	wt. bhp	wt. SO4	wt. bhp	wt. SO4
DB-2	31.5%	6.0	120.16	6.0	463.04	6.0	894
Idle	19.0%	2.5	26.10	2.5	45.03	2.5	303
Notch 1	6.5%	13.3	14.44	13.3	34.09	13.3	225
Notch 2	6.5%	28.5	23.99	28.5	36.18	28.4	688
Notch 3	5.2%	51.0	37.96	50.9	87.18	51.0	1,796
Notch 4	4.4%	66.8	58.45	66.8	170.54	66.8	3,452
Notch 5	3.8%	75.6	136.12	75.8	407.62	74.9	4,291
Notch 6	3.9%	112.4	270.20	112.5	663.16	112.4	5,431
Notch 7	3.0%	109.7	289.30	109.7	619.35	109.7	1,346
Notch 8	16.2%	681.6	1795.01	681.9	4531.21	681.7	10,935
	Total	**1147.4**	**2771.7**	**1147.9**	**7057.4**	**1146.8**	**29,362**
EPA Line-Haul Duty Cycle Weighted Sulfate Emissions, mg/hp-hr			**2.42**		**6.15**		**26**

APPENDIX L-4: EPA LINE-HAUL DUTY-CYCLE WEIGHTED GE SULFATE EMISSIONS SUMMARY

UP 9715

		CARB Diesel		On-Highway Diesel		High-Sulfur, Nonroad	
	WF	wt. bhp	wt. SO4	wt. bhp	wt. SO4	wt. bhp	wt. SO4
DB-2	12.5%	2.8	92.3	3.1	14.4	2.9	230
Low Idle	19.0%	1.9	44.0	2.1	13.4	1.9	207
Idle	19.0%	2.7	39.6	2.1	16.9	2.1	282
Notch 1	6.5%	12.7	24.4	11.6	15.7	12.6	312
Notch 2	6.5%	32.7	98.5	33.0	40.8	32.2	1,496
Notch 3	5.2%	53.9	677.1	53.8	108.7	53.1	3,567
Notch 4	4.4%	68.3	715.5	68.2	306.3	67.7	3,713
Notch 5	3.8%	84.4	786.9	84.6	414.9	84.5	4,059
Notch 6	3.9%	114.7	678.5	114.7	392.7	114.7	5,091
Notch 7	3.0%	109.9	397.8	110.0	376.8	110.0	4,998
Notch 8	16.2%	727.2	1776.1	725.4	2283.5	726.4	33,366
	Total	**1211.1**	**5330.6**	**1208.5**	**3984.1**	**1208.0**	**57,321**
EPA Line-Haul Duty Cycle Weighted Sulfate Emissions, mg/hp-hr			**4.40**		**3.30**		**47**

UP 9724

		CARB Diesel		On-Highway Diesel		High-Sulfur, Nonroad	
	WF	wt. bhp	wt. SO4	wt. bhp	wt. SO4	wt. bhp	wt. SO4
DB-2	12.5%	3.1	43.09	2.9	67.32	3.1	284
Low Idle	19.0%	2.3	60.53	2.3	49.02	2.1	197
Idle	19.0%	2.3	52.22	2.3	62.22	2.3	219
Notch 1	6.5%	12.8	28.73	12.8	48.10	12.9	277
Notch 2	6.5%	32.3	92.05	32.2	199.74	32.2	1,527
Notch 3	5.2%	53.9	314.09	53.7	452.99	53.8	3,301
Notch 4	4.4%	68.1	696.83	68.2	667.96	68.2	3,870
Notch 5	3.8%	84.6	982.07	84.5	723.94	84.6	3,620
Notch 6	3.9%	114.8	700.46	114.7	488.04	114.7	4,655
Notch 7	3.0%	109.9	365.80	109.9	357.08	109.8	6,446
Notch 8	16.2%	729.2	1814.87	727.4	1926.32	729.2	48,924
	Total	**1213.3**	**5150.8**	**1210.7**	**5042.7**	**1213.0**	**73,319**
EPA Line-Haul Duty Cycle Weighted Sulfate Emissions, mg/hp-hr			**4.25**		**4.17**		**60**

UP 9733

		CARB Diesel		On-Highway Diesel		High-Sulfur, Nonroad	
	WF	wt. bhp	wt. SO4	wt. bhp	wt. SO4	wt. bhp	wt. SO4
DB-2	12.5%	2.9	37.60	2.9	30.07	2.8	194
Low Idle	19.0%	1.9	10.69	1.9	20.08	1.9	169
Idle	19.0%	1.9	26.66	1.9	23.20	1.9	263
Notch 1	6.5%	12.4	9.28	12.4	15.29	12.5	235
Notch 2	6.5%	32.4	10.76	32.3	28.95	32.4	1,116
Notch 3	5.2%	54.0	39.95	54.0	76.19	53.8	3,301
Notch 4	4.4%	68.2	168.17	68.2	185.15	68.2	3,893
Notch 5	3.8%	84.4	415.82	84.5	304.87	84.5	4,418
Notch 6	3.9%	114.6	322.59	114.7	323.60	114.6	4,977
Notch 7	3.0%	110.0	252.70	110.0	291.48	109.9	2,839
Notch 8	16.2%	727.5	1274.18	730.0	1702.81	728.4	33,941
	Total	**1210.0**	**2568.4**	**1212.6**	**3001.7**	**1210.9**	**55,346**
EPA Line-Haul Duty Cycle Weighted Sulfate Emissions, mg/hp-hr			**2.12**		**2.48**		**46**

APPENDIX M

SOF of Particulate Data

Appendix M: Soluble Organic Fraction of PM for the EMD Locomotives

BNSF 9693

	CARB diesel (EM-2663-F)					On-Hwy Diesel (EM-2677-F)					High Sulfur, Nonroad diesel (EM-2664-F)				
TEST NO.	Total Part., g/hp-hr	Total Part. g/hr	% SOF	SOF, mg/hp-hr	SOF, mg/hr	Total Part. g/hp-hr	Total Part. g/hr	% SOF	SOF, mg/hp-hr	SOF, mg/hr	Total Part. g/hp-hr	Total Part. g/hr	% SOF	SOF, mg/hp-hr	SOF, mg/hr
DB-2	1.711	33.0	68.9	1178.9	22,737	1.605	31.0	63.3	1016.0	19,623	1.825	35.0	72.0	1314.0	25,200
Idle	1.091	15.0	62.6	683.0	9,390	1.263	17.0	63.9	807.1	10,863	1.249	17.0	57.9	723.2	9,843
Notch 1	0.265	54.0	67.3	178.3	36,342	0.242	50.0	58.1	140.6	29,050	0.239	49.0	60.1	143.6	29,449
Notch 2	0.242	106.0	73.4	177.6	77,804	0.206	90.0	62.6	129.0	56,340	0.228	100.0	63.5	144.8	63,500
Notch 3	0.247	243.0	79.8	197.1	193,914	0.220	216.0	79.1	174.0	170,856	0.270	264.0	77.0	207.9	203,280
Notch 4	0.254	387.0	68.0	172.7	263,160	0.235	356.0	67.6	158.9	240,656	0.297	452.0	69.8	207.3	315,496
Notch 5	0.268	538.0	55.8	149.5	300,204	0.250	502.0	55.0	137.5	276,100	0.329	660.0	63.4	208.6	418,440
Notch 6	0.336	968.0	42.5	142.8	411,400	0.309	890.0	47.7	147.4	424,530	0.388	1118.0	52.8	204.9	590,304
Notch 7	0.280	1023.0	64.6	180.9	660,858	0.306	1119.0	70.5	215.7	788,895	0.336	1228.0	67.5	226.8	828,900
Notch 8	0.507	2135.0	83.1	421.3	1,774,185	0.519	2184.0	84.2	437.0	1,838,928	0.551	2318.0	82.6	455.1	1,914,668

BNSF 9754

	CARB diesel (EM-2663-F)					On-Hwy Diesel (EM-2677-F)					High Sulfur, Nonroad diesel (EM-2664-F)				
TEST NO.	Total Part., g/hp-hr	Total Part. g/hr	% SOF	SOF, mg/hp-hr	SOF, mg/hr	Total Part. g/hp-hr	Total Part. g/hr	% SOF	SOF, mg/hp-hr	SOF, mg/hr	Total Part. g/hp-hr	Total Part. g/hr	% SOF	SOF, mg/hp-hr	SOF, mg/hr
DB-2	2.719	52.0	75.2	2044.7	39,104	2.222	43.0	71.1	1579.8	30,573	2.328	45.0	68.5	1594.7	30,825
Idle	1.461	20.0	67.8	990.6	13,560	1.535	21.0	62.1	953.2	13,041	1.492	20.0	65.8	981.7	13,160
Notch 1	0.284	58.0	67.6	192.0	39,208	0.230	47.0	72.2	166.1	33,934	0.270	55.0	62.8	169.6	34,540
Notch 2	0.231	101.0	70.6	163.1	71,306	0.234	103.0	72.5	169.7	74,675	0.264	116.0	66.5	175.6	77,140
Notch 3	0.297	290.0	82.5	245.0	239,250	0.308	302.0	86.4	266.1	260,928	0.322	315.0	77.8	250.5	245,070
Notch 4	0.305	462.0	74.8	228.1	345,576	0.307	466.0	83.7	257.0	390,042	0.347	525.0	66.6	231.1	349,650
Notch 5	0.283	567.0	61.6	174.3	349,272	0.282	566.0	78.3	220.8	443,178	0.400	801.0	60.0	240.0	480,600
Notch 6	0.333	958.0	56.8	189.1	544,144	0.311	896.0	75.5	234.8	676,480	0.435	1247.0	55.7	242.3	694,579
Notch 7	0.324	1185.0	71.9	233.0	852,015	0.352	1287.0	84.6	297.8	1,088,802	0.352	1284.0	67.3	236.9	864,132
Notch 8	0.344	1447.0	74.6	256.6	1,079,462	0.364	1532.0	87.1	317.0	1,334,372	0.352	1488.0	71.8	252.7	1,068,384

BNSF 9696

	CARB diesel (EM-2663-F)					On-Hwy Diesel (EM-2677-F)					High Sulfur, Nonroad diesel (EM-2664-F)				
TEST NO.	Total Part., g/hp-hr	Total Part. g/hr	% SOF	SOF, mg/hp-hr	SOF, mg/hr	Total Part. g/hp-hr	Total Part. g/hr	% SOF	SOF, mg/hp-hr	SOF, mg/hr	Total Part. g/hp-hr	Total Part. g/hr	% SOF	SOF, mg/hp-hr	SOF, mg/hr
DB-2	1.933	37.0	71.6	1384.0	26,492	2.418	46.0	66.9	1617.6	30,774	2.337	44.0	68.2	1593.8	30,008
Idle	0.980	13.0	73.6	721.3	9,568	1.087	15.0	68.5	744.6	10,275	1.399	19.0	67.5	944.3	12,825
Notch 1	0.205	42.0	72.1	147.8	30,282	0.243	50.0	73.4	178.4	36,700	0.208	43.0	69.7	145.0	29,971
Notch 2	0.211	92.0	77.7	163.9	71,484	0.249	109.0	77.4	192.7	84,366	0.240	105.0	67.1	161.0	70,455
Notch 3	0.234	229.0	80.6	188.6	184,574	0.282	276.0	80.3	226.4	221,628	0.276	270.0	75.6	208.7	204,120
Notch 4	0.245	372.0	56.3	137.9	209,436	0.261	396.0	60.8	158.7	240,768	0.350	531.0	62.3	218.1	330,813
Notch 5	0.244	486.0	47.8	116.6	232,308	0.258	515.0	48.1	124.1	247,715	0.339	669.0	55.4	187.8	370,626
Notch 6	0.202	581.0	64.4	130.1	374,164	0.231	666.0	70.0	161.7	466,200	0.295	851.0	72.2	213.0	614,422
Notch 7	0.215	786.0	80.6	173.3	633,516	0.242	886.0	83.6	202.3	740,696	0.262	957.0	78.8	206.5	754,116
Notch 8	0.213	896.0	80.1	170.6	717,696	0.244	1026.0	79.4	193.7	814,644	0.297	1249.0	83.1	246.8	1,037,919

Appendix M: Soluble Organic Fraction of PM for the EMD Locomotives
EPA Line-Haul Duty-Cycle Weighted SOF

BNSF 9693		2663 (Sept. 17)		2677 (Sept. 16)		2664 (Sept. 17)	
		wt. bhp	wt. SOF	wt. bhp	wt. SOF	wt. bhp	wt. SOF
DB-2	31.5%	6.1	7162	6.1	6181	6.1	7938
Idle	19.0%	2.6	1784	2.6	2064	2.6	1870
Notch 1	6.5%	13.3	2362	13.3	1888	13.4	1914
Notch 2	6.5%	28.4	5057	28.4	3662	28.5	4128
Notch 3	5.2%	51.0	10084	50.9	8885	50.9	10571
Notch 4	4.4%	66.8	11579	66.8	10589	66.8	13882
Notch 5	3.8%	76.2	11408	76.2	10492	76.3	15901
Notch 6	3.9%	112.4	16045	112.4	16557	112.5	23022
Notch 7	3.0%	109.6	19826	109.7	23667	109.7	24867
Notch 8	16.2%	681.6	287418	682.0	297906	681.8	310176
Total		**1148.0**	**372724.4**	**1148.4**	**381890.6**	**1148.5**	**414268.0**
EPA Line-Haul Duty Cycle Weighted SOF Emissions			**325**		**333**		**361**

BNSF 9754		2663 (Oct. 5)		2677 (Oct. 6)		2664 (Oct. 5)	
		wt. bhp	wt. SOF	wt. bhp	wt. SOF	wt. bhp	wt. SOF
DB-2	31.5%	6.0	12318	6.0	9630	6.0	9710
Idle	19.0%	2.6	2576	2.6	2478	2.6	2500
Notch 1	6.5%	13.3	2549	13.3	2206	13.3	2245
Notch 2	6.5%	28.4	4635	28.5	4854	28.5	5014
Notch 3	5.2%	50.9	12441	51.0	13568	51.0	12744
Notch 4	4.4%	66.7	15205	66.7	17162	66.6	15385
Notch 5	3.8%	76.2	13272	76.2	16841	76.1	18263
Notch 6	3.9%	112.3	21222	112.4	26383	111.8	27089
Notch 7	3.0%	109.6	25560	109.7	32664	109.5	25924
Notch 8	16.2%	681.7	174873	682.0	216168	685.0	173078
Total		**1147.7**	**284651.2**	**1148.3**	**341953.8**	**1150.4**	**291951.3**
EPA Line-Haul Duty Cycle Weighted SOF Emissions			**248**		**298**		**254**

BNSF 9696		2663 (Mar. 11)		2677 (Mar. 10)		2664 (Mar. 12)	
		wt. bhp	wt. SOF	wt. bhp	wt. SOF	wt. bhp	wt. SOF
DB-2	31.5%	6.0	8345	6.0	9694	6.0	9453
Idle	19.0%	2.5	1818	2.5	1952	2.5	2437
Notch 1	6.5%	13.3	1968	13.3	2386	13.3	1948
Notch 2	6.5%	28.5	4646	28.5	5484	28.4	4580
Notch 3	5.2%	51.0	9598	50.9	11525	51.0	10614
Notch 4	4.4%	66.8	9215	66.8	10594	66.8	14556
Notch 5	3.8%	75.6	8828	75.8	9413	74.9	14084
Notch 6	3.9%	112.4	14592	112.5	18182	112.4	23962
Notch 7	3.0%	109.7	19005	109.7	22221	109.7	22623
Notch 8	16.2%	681.6	116267	681.9	131972	681.7	168143
Total		**1147.4**	**194283.1**	**1147.9**	**223422.0**	**1146.8**	**272399.6**
EPA Line-Haul Duty Cycle Weighted SOF Emissions			**169**		**195**		**238**

Appendix M: Soluble Organic Fraction of PM for the GE Locomotives

UP 9715

	CARB diesel (EM-2663-F)					On-Hwy Diesel (EM-2677-F)					High Sulfur, Nonroad diesel (EM-2664-F)					0.3% Sulfur Diesel (EM-2708-F)				
TEST NO.	Total Part., g/hp-hr	Total Part. g/hr	% SOF	SOF, mg/hp-hr	SOF, mg/hr	Total Part. g/hp-hr	Total Part. g/hr	% SOF	SOF, mg/hp-hr	SOF, mg/hr	Total Part. g/hp-hr	Total Part. g/hr	% SOF	SOF, mg/hp-hr	SOF, mg/hr	Total Part. g/hp-hr	Total Part. g/hr	% SOF	SOF, mg/hp-hr	SOF, mg/hr
DB-2	0.931	30.0	49.3	459.0	14,790	1.284	32.0	56.1	720.3	17,952	1.126	37.0	59.1	665.5	21,867	1.068	35.0	53.7	573.5	18,795
Low Idle	1.707	22.0	45.1	769.9	9,922	2.145	24.0	52.0	1115.4	12,480	3.150	35.0	68.6	2160.9	24,010	2.916	32.0	59.4	1732.1	19,008
Idle	1.625	19.0	51.7	840.1	9,823	2.087	23.0	49.9	1041.4	11,477	2.131	26.0	59.3	1263.7	15,418	2.210	24.0	60.5	1337.1	14,520
Notch 1	0.139	27.0	78.6	109.3	21,222	0.126	25.0	83.3	105.0	20,825	0.161	31.0	74.5	119.9	23,095	0.122	24.0	72.7	88.7	17,448
Notch 2	0.111	55.0	77.5	86.0	42,625	0.098	49.0	74.8	73.3	36,652	0.136	67.0	71.4	97.1	47,838	0.102	51.0	69.1	70.5	35,241
Notch 3	0.170	176.0	59.8	101.7	105,248	0.141	146.0	65.4	92.2	95,484	0.194	202.0	70.8	137.4	143,016	0.152	156.0	56.2	85.4	87,672
Notch 4	0.194	300.0	47.1	91.4	141,300	0.161	249.0	38.8	62.5	96,612	0.213	330.0	55.8	118.9	184,140	0.153	238.0	38.5	58.9	91,630
Notch 5	0.166	368.0	43.7	72.5	160,816	0.168	373.0	44.3	74.4	165,239	0.209	465.0	54.1	113.1	251,565	0.160	356.0	51.1	81.8	181,916
Notch 6	0.120	353.0	43.7	52.4	154,261	0.139	408.0	42.7	59.4	174,216	0.182	536.0	54.5	99.2	292,120	0.145	427.0	43.0	62.4	183,610
Notch 7	0.096	351.0	43.5	41.8	152,685	0.119	436.0	45.7	54.4	199,252	0.182	665.0	59.4	108.1	395,010	0.130	488.0	45.5	59.2	222,040
Notch 8	0.110	492.0	36.0	39.6	177,120	0.124	558.0	36.0	44.6	200,880	0.189	849.0	53.9	101.9	457,611	0.140	630.0	46.1	64.5	290,430

UP 9724

	CARB diesel (EM-2663-F)					On-Hwy Diesel (EM-2677-F)					High Sulfur, Nonroad diesel (EM-2664-F)					0.3% Sulfur Diesel (EM-2708-F)				
TEST NO.	Total Part., g/hp-hr	Total Part. g/hr	% SOF	SOF, mg/hp-hr	SOF, mg/hr	Total Part. g/hp-hr	Total Part. g/hr	% SOF	SOF, mg/hp-hr	SOF, mg/hr	Total Part. g/hp-hr	Total Part. g/hr	% SOF	SOF, mg/hp-hr	SOF, mg/hr	Total Part. g/hp-hr	Total Part. g/hr	% SOF	SOF, mg/hp-hr	SOF, mg/hr
DB-2	1.730	62.0	67.7	1171.2	41,974	2.899	75.0	70.0	2029.3	52,500	2.782	72.0	68.5	1905.67	49,320	4.001	100.0	77.6	3104.8	77,600
Low Idle	2.314	49.0	46.8	1083.0	22,932	3.637	51.0	46.9	1705.8	23,919	4.616	60.0	64.9	2995.78	38,940	5.740	75.0	62.5	3587.5	46,875
Idle	1.467	31.0	52.7	773.1	16,337	2.349	33.0	59.6	1400.0	19,668	4.403	53.0	63.1	2778.29	33,443	4.529	54.0	63.5	2875.9	34,290
Notch 1	0.286	57.0	84.3	241.1	48,051	0.447	88.0	87.6	391.6	77,088	0.453	88.0	86.1	390.03	75,768	0.622	121.0	89.4	556.1	108,174
Notch 2	0.263	131.0	71.5	188.0	93,665	0.330	165.0	82.7	272.9	136,455	0.336	167.0	77.6	260.74	129,592	0.421	209.0	81.8	344.4	170,962
Notch 3	0.248	256.0	51.5	127.7	131,840	0.215	224.0	56.3	121.0	126,112	0.252	261.0	64.0	161.28	167,040	0.299	310.0	62.7	187.5	194,370
Notch 4	0.218	339.0	31.1	67.8	105,429	0.183	284.0	25.7	47.0	72,988	0.229	355.0	49.4	113.13	175,370	0.234	363.0	47.2	110.4	171,336
Notch 5	0.152	338.0	39.6	60.2	133,848	0.149	332.0	37.6	56.0	124,832	0.186	415.0	56.7	105.46	235,305	0.185	411.0	50.0	92.5	205,500
Notch 6	0.127	374.0	41.7	53.0	155,958	0.123	362.0	38.7	47.6	140,094	0.171	503.0	57.1	97.64	287,213	0.155	456.0	48.8	75.6	222,528
Notch 7	0.100	368.0	46.4	46.4	170,752	0.105	382.0	45.4	47.7	173,428	0.162	592.0	62.0	100.44	367,040	0.136	498.0	51.8	70.4	257,964
Notch 8	0.099	445.0	44.7	44.3	198,915	0.100	450.0	44.5	44.5	200,250	0.189	850.0	67.0	126.63	569,500	0.142	640.0	58.8	83.5	376,320

UP 9733

	CARB diesel (EM-2663-F)					On-Hwy Diesel (EM-2677-F)					High Sulfur, Nonroad diesel (EM-2664-F)					0.3% Sulfur Diesel (EM-2708-F)				
TEST NO.	Total Part., g/hp-hr	Total Part. g/hr	% SOF	SOF, mg/hp-hr	SOF, mg/hr	Total Part. g/hp-hr	Total Part. g/hr	% SOF	SOF, mg/hp-hr	SOF, mg/hr	Total Part. g/hp-hr	Total Part. g/hr	% SOF	SOF, mg/hp-hr	SOF, mg/hr	Total Part. g/hp-hr	Total Part. g/hr	% SOF	SOF, mg/hp-hr	SOF, mg/hr
DB-2	1.531	35.0	66.2	1013.5	23,170	1.793	41.0	68.7	1231.8	28,167	1.696	37.0	67.4	1143.10	24,938	nd	nd	nd	nd	nd
Low Idle	1.718	17.0	61.1	1049.7	10,387	2.338	23.0	63.5	1484.6	14,605	2.340	23.0	74.5	1743.30	17,135	nd	nd	nd	nd	nd
Idle	1.687	17.0	62.3	1051.0	10,591	2.463	25.0	71.6	1763.5	17,900	2.864	29.0	66.4	1901.70	19,256	nd	nd	nd	nd	nd
Notch 1	0.194	37.0	85.5	165.9	31,635	0.253	48.0	88.5	223.9	42,480	0.264	51.0	86.8	229.15	44,268	nd	nd	nd	nd	nd
Notch 2	0.136	68.0	83.4	113.4	56,712	0.185	92.0	89.1	164.8	81,972	0.215	108.0	86.9	186.84	93,852	nd	nd	nd	nd	nd
Notch 3	0.124	128.0	66.8	82.8	85,504	0.133	138.0	66.5	88.4	91,770	0.261	270.0	81.3	212.19	219,510	nd	nd	nd	nd	nd
Notch 4	0.139	215.0	34.1	47.4	73,315	0.124	193.0	42.5	52.7	82,025	0.230	357.0	69.6	160.08	248,472	nd	nd	nd	nd	nd
Notch 5	0.123	273.0	51.0	62.7	139,230	0.117	260.0	50.2	58.7	130,520	0.206	459.0	75.4	155.32	346,086	nd	nd	nd	nd	nd
Notch 6	0.081	240.0	36.8	29.8	88,320	0.093	275.0	42.8	39.8	117,700	0.170	500.0	63.6	108.12	318,000	nd	nd	nd	nd	nd
Notch 7	0.074	273.0	40.1	29.7	109,473	0.084	308.0	36.0	30.2	110,880	0.155	567.0	62.4	96.72	353,808	nd	nd	nd	nd	nd
Notch 8	0.101	453.0	29.2	29.5	132,276	0.117	527.0	23.7	27.7	124,899	0.188	847.0	53.6	100.77	453,992	nd	nd	nd	nd	nd

Appendix M: SOF Summary for GE Locomotives

UP 9715		2663 (Oct 26)		2677 (Oct. 27)		2664 (Oct. 27)		2708 (Oct. 30)	
		wt. bhp	wt. SOF	wt. bhp	wt. SOF	wt. bhp	wt. SOF	wt. bhp	wt. SOF
DB-2	12.5%	4.0	1849	3.1	2244	4.1	2733	4.1	2,349
Low Idle	19.0%	2.5	1885	2.1	2371	2.1	4562	2.1	3,612
Idle	19.0%	2.3	1866	2.1	2181	2.3	2929	2.1	2,759
Notch 1	6.5%	12.5	1379	12.8	1354	12.7	1501	12.8	1,134
Notch 2	6.5%	32.2	2771	32.3	2382	32.4	3109	32.6	2,291
Notch 3	5.2%	53.9	5473	53.8	4965	54.2	7437	53.2	4,559
Notch 4	4.4%	68.2	6217	68.2	4251	68.2	8102	68.2	4,032
Notch 5	3.8%	84.5	6111	84.5	6279	84.5	9559	84.5	6,913
Notch 6	3.9%	114.6	6016	114.7	6794	114.6	11393	114.7	7,161
Notch 7	3.0%	110.0	4581	110.0	5978	109.9	11850	112.3	6,661
Notch 8	16.2%	727.2	28693	728.2	32543	727.9	74133	727.9	47,050
	Total	**1211.8**	**66841.6**	**1211.9**	**71341.6**	**1212.8**	**137309.8**	**1214.6**	**88,520**
EPA Line-Haul Duty Cycle Weighted SOF Emissions			**55**		**59**		**113**		**73**

UP 9724		2663 (Nov. 29)		2677 (Nov. 29)		2664 (Nov. 30)		2708 (Nov. 30)	
		wt. bhp	wt. SOF	wt. bhp	wt. SOF	wt. bhp	wt. SOF	wt. bhp	wt. SOF
DB-2	12.5%	4.5	5247	3.3	6563	3.3	6165	3.1	9,700
Low Idle	19.0%	4.0	4357	2.7	4545	2.5	7399	2.5	8,906
Idle	19.0%	4.0	3104	2.7	3737	2.3	6354	2.3	6,515
Notch 1	6.5%	12.9	3123	12.7	5011	12.6	4925	12.7	7,031
Notch 2	6.5%	32.4	6088	32.5	8870	32.4	8423	32.2	11,113
Notch 3	5.2%	53.7	6856	54.1	6558	53.8	8686	53.9	10,107
Notch 4	4.4%	68.3	4639	68.2	3211	68.1	7716	68.1	7,539
Notch 5	3.8%	84.4	5086	84.5	4744	84.6	8942	84.4	7,809
Notch 6	3.9%	114.6	6082	114.7	5464	114.7	11201	114.7	8,679
Notch 7	3.0%	109.9	5123	109.8	5203	109.9	11011	109.8	7,739
Notch 8	16.2%	728.7	32224	728.8	32441	729.0	92259	728.8	60,964
	Total	**1217.4**	**81929.3**	**1214.0**	**86344.2**	**1213.1**	**173081.6**	**1212.6**	**146,102**
EPA Line-Haul Duty Cycle Weighted SOF Emissions			**67**		**71**		**143**		**120**

UP 9733		2663 (May 18)		2677 (May 19)		2664 (May 21)		2708 (May 20)	
		wt. bhp	wt. SOF	wt. bhp	wt. SOF	wt. bhp	wt. SOF	wt. bhp	wt. SOF
DB-2	12.5%	2.9	2896	2.9	3521	2.8	3117		nd
Low Idle	19.0%	1.9	1974	1.9	2775	1.9	3256		nd
Idle	19.0%	1.9	2012	1.9	3401	1.9	3659		nd
Notch 1	6.5%	12.4	2056	12.4	2761	12.5	2877		nd
Notch 2	6.5%	32.4	3686	32.3	5328	32.4	6100		nd
Notch 3	5.2%	54.0	4446	54.0	4772	53.8	11415		nd
Notch 4	4.4%	68.2	3226	68.2	3609	68.2	10933		nd
Notch 5	3.8%	84.4	5291	84.5	4960	84.5	13151		nd
Notch 6	3.9%	114.6	3444	114.7	4590	114.6	12402		nd
Notch 7	3.0%	110.0	3284	110.0	3326	109.9	10614		nd
Notch 8	16.2%	727.5	21429	730.0	20234	728.4	73547		nd
	Total	**1210.0**	**53744.8**	**1212.6**	**59277.4**	**1210.9**	**151070.8**	**1212.6**	nd
EPA Line-Haul Duty Cycle Weighted SOF Emissions			**44**		**49**		**125**		nd

APPENDIX N-1

DDC Series 60 Transient Test Data

CARB Locomotive Fuel Effects Study

DDC 12.7L Series 60, S/N 6RE001123

		BS Emissions (g/hp-hr)				BSFC
Test	**Fuel**	**HC**	**CO**	**NOx**	**PM**	**(lb/hp-hr)**
CARB-HOT-1	CARB	0.098	2.311	4.286	0.205	0.378
CARB-HOT-2	CARB	0.094	2.253	4.455	0.205	0.379
CARB-HOT-3	CARB	0.109	2.225	4.350	0.198	0.372
CARB-HOT-4	CARB	0.084	2.255	4.373	0.197	0.376
Average		**0.096**	**2.261**	**4.366**	**0.201**	**0.376**
COV		**11%**	**2%**	**2%**	**2%**	**1%**
ONHWY-HOT-1	ONHWY	0.117	2.356	4.609	0.209	0.368
ONHWY-HOT-2	ONHWY	0.121	2.365	4.591	0.206	0.373
ONHWY-HOT-3	ONHWY	0.124	2.481	4.645	0.213	0.376
ONHWY-HOT-4	ONHWY	0.111	2.411	4.580	0.210	0.375
Average		**0.118**	**2.403**	**4.606**	**0.210**	**0.373**
COV		**5%**	**2%**	**1%**	**1%**	**1%**
NONRD-HOT-1	NONRD	0.105	2.567	4.756	0.272	0.376
NONRD-HOT-2	NONRD	0.110	2.510	4.677	0.276	0.372
NONRD-HOT-3	NONRD	0.114	2.520	4.838	0.252	0.372
NONRD-HOT-4	NONRD	0.097	2.441	4.777	0.256	0.371
Average		**0.107**	**2.510**	**4.762**	**0.264**	**0.373**
COV		**7%**	**2%**	**1%**	**4%**	**1%**
carb vs nonroad		-9.6%	-9.9%	-8.3%	-23.8%	0.9%
on-hwy vs nonroad		11.0%	-4.2%	-3.3%	-20.6%	0.1%
carb vs on-hwy		-18.6%	-5.9%	-5.2%	-3.9%	0.9%

Updated 30July99 sgf

Southwest Research Institute - Department of Emissions Research
EPA Hot Transient Emission Test Results
Project No. 08-2062-004

Engine Model:	91 DDC Series 60	Test No.: CARB-HOT-1	DIESEL CARB, EM-2663-F
Engine Desc.:	12.7 L (775 CID) 6	Date: 03/30/1999 Time:	HCR: 1.876 FID Resp: 1.00
Engine Cycle:	Diesel	Program HDT: 4.04-R	H= 0.136 C= 0.864 O= 0.000 X= 0.000
Engine S/N:	6RE001123	Cell: 4 Bag Cart: 2	

Ambient/Test Cell Conditions

Barometer:	29.26	in Hg	99.1 kPa
Engine Inlet Air			
Temperature:	74.0	°F	23.3 °C
Dew Point:	59.2	°F	15.1 °C
Abs. Humidity:	77.1	gr/lb	11.0 g/kg
Rel. Humidity:	60	%	
Dilution Air:			
Temperature:	75.0	°F	23.9 °C
Abs. Humidity	58.8	gr/lb	8.4 g/kg
Rel. Humidity:	44	%	

Measured Gaseous Data

	Meter	Range	Concentration		
HC Sample	n/a		5.28	ppm	
HC Bckgrd	n/a		3.00	ppm	
CO Sample	29.9	2	29.02	ppm	(Dry)
CO Bckgrd	0.4	2	0.39	ppm	
NOx Sample	n/a		32.17	ppm	(Dry)
NOx Bckgrd	0.2	2	0.20	ppm	
CO2 Sample	48.2	1	0.4573	%	(Wet)
CO2 Bckgrd	4.8	1	0.0436	%	

Corrected Concentrations

HC	2.38	ppm
CO	27.98	ppm
NOx	31.41	ppm
CO2	0.4152	%

Mass Emissions

HC	2.415	grams	
CO	57.131	grams	
NOx	105.942	grams	
Particulate	5.069	grams	
CO2	13.324	kg	
Fuel	9.35 lb	4.24	kg

Sample Flows

	scfm	scmm
Blower 1 Rate:	3,078.2	87.18
Blower 2 Rate:	0.0	0.00
90 mm System:		
Gas Meter 1:	1.96	0.06
Gas Meter 2:	3.75	0.11
Sample Rate:	1.79	0.05
Total Flow Rate:	3,080.04	87.23

Particulate Data

Filter Number:	2188.0-1085 (pair)	
Weight Gain:	2.949	mg
Sample Multiplier:	1.719	

Correction Factors

NOx Humidity CF:	1.005
Dry-to-Wet CF, Sample:	0.982
Dry-to-Wet CF, Bckgrd:	0.987
Dilution Factor:	29.10

Test Cycle Data

Sample Time:	1,206.60	sec		
Work:	24.72	hp-hr	18.43	kW-hr
Reference Work:	24.83	hp-hr	18.52	kW-hr
Total Volume (Vmix):	61,939.5	scf	1,754.16	scm

Brake-Specific Emission Results

BSHC	(Cell)	0.098 g/hp-hr	0.131	g/kW-hr
CO		2.311 g/hp-hr	3.099	g/kW-hr
NOx	(Cell)	4.286 g/hp-hr	5.747	g/kW-hr
Particulate		0.205 g/hp-hr	0.275	g/kW-hr
CO2		539.0 g/hp-hr	722.81	g/kW-hr
BSFC		0.378 lb/hp-hr	0.230	kg/kW-hr

Southwest Research Institute - Department of Emissions Research
EPA Hot Transient Emission Test Results
Project No. 08-2062-004

Engine Model:	91 DDC Series 60	Test No.: CARB-HOT-2	DIESEL CARB, EM-2663-F
Engine Desc.:	12.7 L (775 CID) 6	Date: 03/30/1999 Time: 10:25	HCR: 1.876 FID Resp: 1.00
Engine Cycle:	Diesel	Program HDT: 4.04-R	H= 0.136 C= 0.864 O= 0.000 X= 0.000
Engine S/N:	6RE001123	Cell: 4 Bag Cart: 2	

Ambient/Test Cell Conditions

Barometer:	29.26	in Hg	99.1 kPa
Engine Inlet Air			
Temperature:	74.0	°F	23.3 °C
Dew Point:	59.3	°F	15.2 °C
Abs. Humidity:	77.4	gr/lb	11.1 g/kg
Rel. Humidity:	60	%	
Dilution Air:			
Temperature:	75.0	°F	23.9 °C
Abs. Humidity	63.4	gr/lb	9.1 g/kg
Rel. Humidity:	48	%	

Measured Gaseous Data

	Meter	Range	Concentration		
HC Sample	n/a		5.19	ppm	
HC Bckgrd	n/a		3.00	ppm	
CO Sample	29.1	2	28.24	ppm	(Dry)
CO Bckgrd	0.2	2	0.19	ppm	
NOx Sample	n/a		33.47	ppm	(Dry)
NOx Bckgrd	0.1	2	0.10	ppm	
CO2 Sample	48.6	1	0.4612	%	(Wet)
CO2 Bckgrd	4.9	1	0.0445	%	

Corrected Concentrations

HC	2.29	ppm
CO	27.37	ppm
NOx	32.75	ppm
CO2	0.4182	%

Mass Emissions

HC	2.323	grams
CO	55.845	grams
NOx	110.435	grams
Particulate	5.086	grams
CO2	13.410	kg
Fuel	9.41 lb	4.27 kg

Sample Flows

	scfm	scmm
Blower 1 Rate:	3,075.2	87.09
Blower 2 Rate:	0.0	0.00
90 mm System:		
Gas Meter 1:	1.96	0.06
Gas Meter 2:	3.76	0.11
Sample Rate:	1.80	0.05
Total Flow Rate:	3,076.99	87.14

Particulate Data

Filter Number:	2189.0-1086 (pair)	
Weight Gain:	2.978	mg
Sample Multiplier:	1.708	

Correction Factors

NOx Humidity CF:	1.006
Dry-to-Wet CF, Sample:	0.981
Dry-to-Wet CF, Bckgrd:	0.986
Dilution Factor:	28.86

Test Cycle Data

Sample Time:	1,206.70	sec		
Work:	24.79	hp-hr	18.49	kW-hr
Reference Work:	24.83	hp-hr	18.52	kW-hr
Total Volume (Vmix):	61,883.3	scf	1,752.57	scm

Brake-Specific Emission Results

BSHC (Cell)	0.094	g/hp-hr	0.126	g/kW-hr
CO	2.253	g/hp-hr	3.021	g/kW-hr
NOx (Cell)	4.455	g/hp-hr	5.974	g/kW-hr
Particulate	0.205	g/hp-hr	0.275	g/kW-hr
CO2	540.9	g/hp-hr	725.39	g/kW-hr
BSFC	0.379	lb/hp-hr	0.231	kg/kW-hr

Southwest Research Institute - Department of Emissions Research
EPA Hot Transient Emission Test Results
Project No. 08-2062-004

Engine Model:	91 DDC Series 60	Test No.: CARB-HOT-3	DIESEL CARB, EM-2663-F
Engine Desc.:	12.7 L (775 CID) 6	Date: 04/05/1999 Time: 02:15	HCR: 1.876 FID Resp: 1.00
Engine Cycle:	Diesel	Program HDT: 4.04-R	H= 0.136 C= 0.864 O= 0.000 X= 0.000
Engine S/N:	6RE001123	Cell: 4 Bag Cart: 2	

Ambient/Test Cell Conditions

Barometer:	29.02	in Hg	98.3 kPa
Engine Inlet Air			
Temperature:	74.0	°F	23.3 °C
Dew Point:	59.3	°F	15.2 °C
Abs. Humidity:	78.0	gr/lb	11.1 g/kg
Rel. Humidity:	60	%	
Dilution Air:			
Temperature:	80.0	°F	26.7 °C
Abs. Humidity	29.3	gr/lb	4.2 g/kg
Rel. Humidity:	19	%	

Measured Gaseous Data

	Meter	Range	Concentration		
HC Sample	n/a		5.23	ppm	
HC Bckgrd	n/a		2.60	ppm	
CO Sample	28.7	2	27.85	ppm	(Dry)
CO Bckgrd	n/a	2	0.00	ppm	
NOx Sample	n/a		32.85	ppm	(Dry)
NOx Bckgrd	0.1	2	0.10	ppm	
CO2 Sample	48.2	1	0.4573	%	(Wet)
CO2 Bckgrd	4.7	1	0.0427	%	

Corrected Concentrations

HC	2.72	ppm
CO	27.43	ppm
NOx	32.39	ppm
CO2	0.4161	%

Mass Emissions

HC	2.733	grams	
CO	55.567	grams	
NOx	108.625	grams	
Particulate	4.946	grams	
CO2	13.243	kg	
Fuel	9.29 lb	4.21	kg

Sample Flows

	scfm	scmm
Blower 1 Rate:	3,050.0	86.38
Blower 2 Rate:	0.0	0.00
90 mm System:		
Gas Meter 1:	1.97	0.06
Gas Meter 2:	3.77	0.11
Sample Rate:	1.80	0.05
Total Flow Rate:	3,051.77	86.43

Particulate Data

Filter Number:	2284.0-20 (pair)	
Weight Gain:	2.915	mg
Sample Multiplier:	1.697	

Correction Factors

NOx Humidity CF:	1.008
Dry-to-Wet CF, Sample:	0.989
Dry-to-Wet CF, Bckgrd:	0.993
Dilution Factor:	29.10

Test Cycle Data

Sample Time:	1,207.80	sec		
Work:	24.97	hp-hr	18.62	kW-hr
Reference Work:	24.83	hp-hr	18.52	kW-hr
Total Volume (Vmix):	61,432.2	scf	1,739.80	scm

Brake-Specific Emission Results

BSHC (Cell)	0.109	g/hp-hr	0.147	g/kW-hr
CO	2.225	g/hp-hr	2.984	g/kW-hr
NOx (Cell)	4.350	g/hp-hr	5.834	g/kW-hr
Particulate	0.198	g/hp-hr	0.266	g/kW-hr
CO2	530.3	g/hp-hr	711.20	g/kW-hr
BSFC	0.372	lb/hp-hr	0.226	kg/kW-hr

Southwest Research Institute - Department of Emissions Research
EPA Hot Transient Emission Test Results
Project No. 08-2062-004

Engine Model:	91 DDC Series 60	Test No.: CARB-HOT-4	DIESEL CARB, EM-2663-F
Engine Desc.:	12.7 L (775 CID) 6	Date: 04/05/1999 Time: 02:55	HCR: 1.876 FID Resp: 1.00
Engine Cycle:	Diesel	Program HDT: 4.04-R	H= 0.136 C= 0.864 O= 0.000 X= 0.000
Engine S/N:	6RE001123	Cell: 4 Bag Cart: 2	

Ambient/Test Cell Conditions

Barometer:	29.00	in Hg	98.2 kPa
Engine Inlet Air			
Temperature:	74.0	°F	23.3 °C
Dew Point:	59.2	°F	15.1 °C
Abs. Humidity:	77.8	gr/lb	11.1 g/kg
Rel. Humidity:	60	%	
Dilution Air:			
Temperature:	75.0	°F	23.9 °C
Abs. Humidity	37.6	gr/lb	5.4 g/kg
Rel. Humidity:	28	%	

Measured Gaseous Data

	Meter	Range	Concentration		
HC Sample	n/a		4.98	ppm	
HC Bckgrd	n/a		3.00	ppm	
CO Sample	29.2	2	28.34	ppm	(Dry)
CO Bckgrd	0.1	2	0.10	ppm	
NOx Sample	n/a		33.03	ppm	(Dry)
NOx Bckgrd	0.1	2	0.10	ppm	
CO2 Sample	48.4	1	0.4593	%	(Wet)
CO2 Bckgrd	4.5	1	0.0409	%	

Corrected Concentrations

HC	2.08	ppm
CO	27.73	ppm
NOx	32.51	ppm
CO2	0.4198	%

Mass Emissions

HC	2.093	grams	
CO	56.123	grams	
NOx	108.854	grams	
Particulate	4.900	grams	
CO2	13.350	kg	
Fuel	9.37 lb	4.25	kg

Sample Flows

	scfm	scmm
Blower 1 Rate:	3,047.9	86.32
Blower 2 Rate:	0.0	0.00
90 mm System:		
Gas Meter 1:	1.97	0.06
Gas Meter 2:	3.77	0.11
Sample Rate:	1.79	0.05
Total Flow Rate:	3,049.66	86.37

Particulate Data

Filter Number:	2285.0-21 (pair)	
Weight Gain:	2.879	mg
Sample Multiplier:	1.702	

Correction Factors

NOx Humidity CF:	1.007
Dry-to-Wet CF, Sample:	0.987
Dry-to-Wet CF, Bckgrd:	0.991
Dilution Factor:	28.97

Test Cycle Data

Sample Time:	1,207.60	sec		
Work:	24.89	hp-hr	18.56	kW-hr
Reference Work:	24.83	hp-hr	18.52	kW-hr
Total Volume (Vmix):	61,379.4	scf	1,738.30	scm

Brake-Specific Emission Results

BSHC (Cell)	0.084	g/hp-hr	0.113	g/kW-hr
CO	2.255	g/hp-hr	3.024	g/kW-hr
NOx (Cell)	4.373	g/hp-hr	5.865	g/kW-hr
Particulate	0.197	g/hp-hr	0.264	g/kW-hr
CO2	536.4	g/hp-hr	719.29	g/kW-hr
BSFC	0.376	lb/hp-hr	0.229	kg/kW-hr

Southwest Research Institute - Department of Emissions Research
EPA Hot Transient Emission Test Results
Project No. 08-2062-004

Engine Model:	91 DDC Series 60	Test No.: NONRD-HOT-1	DIESEL NONRD, EM-2708-F
Engine Desc.:	12.7 L (775 CID) 6	Date: 04/01/1999 Time: 02:30	HCR: 1.812 FID Resp: 1.00
Engine Cycle:	Diesel	Program HDT: 4.04-R	H= 0.132 C= 0.868 O= 0.000 X= 0.000
Engine S/N:	6RE001123	Cell: 4 Bag Cart: 2	

Ambient/Test Cell Conditions

Barometer:	28.88	in Hg	97.8 kPa
Engine Inlet Air			
Temperature:	74.0	°F	23.3 °C
Dew Point:	59.6	°F	15.3 °C
Abs. Humidity:	79.3	gr/lb	11.3 g/kg
Rel. Humidity:	61	%	
Dilution Air:			
Temperature:	79.0	°F	26.1 °C
Abs. Humidity	93.8	gr/lb	13.4 g/kg
Rel. Humidity:	61	%	

Measured Gaseous Data

	Meter	Range	Concentration		
HC Sample	n/a		6.20	ppm	
HC Bckgrd	n/a		3.70	ppm	
CO Sample	34.0	2	33.03	ppm	(Dry)
CO Bckgrd	0.3	2	0.29	ppm	
NOx Sample	n/a		36.84	ppm	(Dry)
NOx Bckgrd	1.7	1	0.44	ppm	
CO2 Sample	50.7	1	0.4820	%	(Wet)
CO2 Bckgrd	6.6	1	0.0601	%	

Corrected Concentrations

HC	2.63	ppm
CO	31.80	ppm
NOx	35.48	ppm
CO2	0.4241	%

Mass Emissions

HC	2.621	grams	
CO	64.096	grams	
NOx	118.764	grams	
Particulate	6.791	grams	
CO2	13.429	kg	
Fuel	9.39 lb	4.26	kg

Sample Flows

	scfm	scmm
Blower 1 Rate:	3,035.2	85.96
Blower 2 Rate:	0.0	0.00
90 mm System:		
Gas Meter 1:	1.98	0.06
Gas Meter 2:	3.74	0.11
Sample Rate:	1.76	0.05
Total Flow Rate:	3,036.99	86.01

Particulate Data

Filter Number:	2239.0-6 (pair)	
Weight Gain:	3.940	mg
Sample Multiplier:	1.724	

Correction Factors

NOx Humidity CF:	1.011
Dry-to-Wet CF, Sample:	0.975
Dry-to-Wet CF, Bckgrd:	0.979
Dilution Factor:	27.93

Test Cycle Data

Sample Time:	1,207.60	sec		
Work:	24.97	hp-hr	18.62	kW-hr
Reference Work:	24.83	hp-hr	18.52	kW-hr
Total Volume (Vmix):	61,124.6	scf	1,731.08	scm

Brake-Specific Emission Results

BSHC (Cell)	0.105	g/hp-hr	0.141	g/kW-hr
CO	2.567	g/hp-hr	3.442	g/kW-hr
NOx (Cell)	4.756	g/hp-hr	6.378	g/kW-hr
Particulate	0.272	g/hp-hr	0.365	g/kW-hr
CO2	537.8	g/hp-hr	721.22	g/kW-hr
BSFC	0.376	lb/hp-hr	0.229	kg/kW-hr

Southwest Research Institute - Department of Emissions Research
EPA Hot Transient Emission Test Results
Project No. 08-2062-004

Engine Model:	91 DDC Series 60	Test No.: NONRD-HOT-2	DIESEL NONRD, EM-2708-F
Engine Desc.:	12.7 L (775 CID) 6	Date: 04/01/1999 Time: 03:10	HCR: 1.812 FID Resp: 1.00
Engine Cycle:	Diesel	Program HDT: 4.04-R	H= 0.132 C= 0.868 O= 0.000 X= 0.000
Engine S/N:	6RE001123	Cell: 4 Bag Cart: 2	

Ambient/Test Cell Conditions

Barometer:	28.87	in Hg	97.8 kPa
Engine Inlet Air			
Temperature:	74.0	°F	23.3 °C
Dew Point:	61.1	°F	16.2 °C
Abs. Humidity:	83.7	gr/lb	12.0 g/kg
Rel. Humidity:	64	%	
Dilution Air:			
Temperature:	78.0	°F	25.6 °C
Abs. Humidity	95.5	gr/lb	13.6 g/kg
Rel. Humidity:	64	%	

Measured Gaseous Data

	Meter	Range	Concentration		
HC Sample	n/a		6.31	ppm	
HC Bckgrd	n/a		3.70	ppm	
CO Sample	33.7	2	32.74	ppm	(Dry)
CO Bckgrd	0.8	2	0.78	ppm	
NOx Sample	n/a		35.72	ppm	(Dry)
NOx Bckgrd	1.6	1	0.41	ppm	
CO2 Sample	50.1	1	0.4760	%	(Wet)
CO2 Bckgrd	6.5	1	0.0592	%	

Corrected Concentrations

HC	2.74	ppm
CO	31.03	ppm
NOx	34.40	ppm
CO2	0.4189	%

Mass Emissions

HC	2.727	grams
CO	62.501	grams
NOx	116.468	grams
Particulate	6.877	grams
CO2	13.258	kg
Fuel	9.27 lb	4.20 kg

Sample Flows

	scfm	scmm
Blower 1 Rate:	3,034.0	85.93
Blower 2 Rate:	0.0	0.00
90 mm System:		
Gas Meter 1:	1.98	0.06
Gas Meter 2:	3.76	0.11
Sample Rate:	1.78	0.05
Total Flow Rate:	3,035.82	85.98

Particulate Data

Filter Number:	2244.0-7 (pair)	
Weight Gain:	4.030	mg
Sample Multiplier:	1.706	

Correction Factors

NOx Humidity CF:	1.023
Dry-to-Wet CF, Sample:	0.974
Dry-to-Wet CF, Bckgrd:	0.979
Dilution Factor:	28.28

Test Cycle Data

Sample Time:	1,207.40	sec		
Work:	24.90	hp-hr	18.57	kW-hr
Reference Work:	24.83	hp-hr	18.52	kW-hr
Total Volume (Vmix):	61,090.9	scf	1,730.13	scm

Brake-Specific Emission Results

BSHC	(Cell)	0.110 g/hp-hr	0.147	g/kW-hr
CO		2.510 g/hp-hr	3.366	g/kW-hr
NOx	(Cell)	4.677 g/hp-hr	6.273	g/kW-hr
Particulate		0.276 g/hp-hr	0.370	g/kW-hr
CO2		532.5 g/hp-hr	714.05	g/kW-hr
BSFC		0.372 lb/hp-hr	0.226	kg/kW-hr

Southwest Research Institute - Department of Emissions Research
EPA Hot Transient Emission Test Results
Project No. 08-2062-004

Engine Model:	91 DDC Series 60	Test No.: NONRD-HOT-3	DIESEL NONRD, EM-2708-F
Engine Desc.:	12.7 L (775 CID) 6	Date: 04/06/1999 Time: 03:47	HCR: 1.812 FID Resp: 1.00
Engine Cycle:	Diesel	Program HDT: 4.04-R	H= 0.132 C= 0.868 O= 0.000 X= 0.000
Engine S/N:	6RE001123	Cell: 4 Bag Cart: 2	

Ambient/Test Cell Conditions

Barometer:	29.17	in Hg	98.8 kPa
Engine Inlet Air			
Temperature:	75.0	°F	23.9 °C
Dew Point:	57.4	°F	14.1 °C
Abs. Humidity:	72.4	gr/lb	10.3 g/kg
Rel. Humidity:	54	%	
Dilution Air:			
Temperature:	80.0	°F	26.7 °C
Abs. Humidity	37.4	gr/lb	5.3 g/kg
Rel. Humidity:	24	%	

Measured Gaseous Data

	Meter	Range	Concentration		
HC Sample	n/a		5.29	ppm	
HC Bckgrd	n/a		2.50	ppm	
CO Sample	33.1	2	32.15	ppm	(Dry)
CO Bckgrd	0.3	2	0.29	ppm	
NOx Sample	n/a		37.44	ppm	(Dry)
NOx Bckgrd	0.1	2	0.10	ppm	
CO2 Sample	48.4	1	0.4593	%	(Wet)
CO2 Bckgrd	4.4	1	0.0400	%	

Corrected Concentrations

HC	2.88	ppm
CO	31.34	ppm
NOx	36.87	ppm
CO2	0.4207	%

Mass Emissions

HC		2.852	grams	
CO		62.932	grams	
NOx		120.793	grams	
Particulate		6.303	grams	
CO2		13.273	kg	
Fuel	9.28	lb	4.21	kg

Sample Flows

	scfm	scmm
Blower 1 Rate:	3,024.1	85.64
Blower 2 Rate:	0.0	0.00
90 mm System:		
Gas Meter 1:	1.95	0.06
Gas Meter 2:	3.77	0.11
Sample Rate:	1.82	0.05
Total Flow Rate:	3,025.92	85.70

Particulate Data

Filter Number:	2324.0-25 (pair)	
Weight Gain:	3.791	mg
Sample Multiplier:	1.663	

Correction Factors

NOx Humidity CF:	0.993
Dry-to-Wet CF, Sample:	0.987
Dry-to-Wet CF, Bckgrd:	0.991
Dilution Factor:	29.31

Test Cycle Data

Sample Time:	1,207.60	sec		
Work:	24.97	hp-hr	18.62	kW-hr
Reference Work:	24.83	hp-hr	18.52	kW-hr
Total Volume (Vmix):	60,901.7	scf	1,724.77	scm

Brake-Specific Emission Results

BSHC	(Cell)	0.114 g/hp-hr	0.153	g/kW-hr
CO		2.520 g/hp-hr	3.380	g/kW-hr
NOx	(Cell)	4.838 g/hp-hr	6.487	g/kW-hr
Particulate		0.252 g/hp-hr	0.338	g/kW-hr
CO2		531.6 g/hp-hr	712.85	g/kW-hr
BSFC		0.372 lb/hp-hr	0.226	kg/kW-hr

Southwest Research Institute - Department of Emissions Research
EPA Hot Transient Emission Test Results
Project No. 08-2062-004

Engine Model:	91 DDC Series 60	Test No.: NONRD-HOT-4	DIESEL NONRD, EM-2708-F
Engine Desc.:	12.7 L (775 CID) 6	Date: 04/06/1999 Time: 04:27	HCR: 1.812 FID Resp: 1.00
Engine Cycle:	Diesel	Program HDT: 4.04-R	H= 0.132 C= 0.868 O= 0.000 X= 0.000
Engine S/N:	6RE001123	Cell: 4 Bag Cart: 2	

Ambient/Test Cell Conditions

Barometer:	29.16	in Hg	98.7 kPa
Engine Inlet Air			
Temperature:	74.0	°F	23.3 °C
Dew Point:	59.2	°F	15.1 °C
Abs. Humidity:	77.3	gr/lb	11.0 g/kg
Rel. Humidity:	60	%	
Dilution Air:			
Temperature:	80.0	°F	26.7 °C
Abs. Humidity	37.4	gr/lb	5.3 g/kg
Rel. Humidity:	24	%	

Measured Gaseous Data

	Meter	Range	Concentration		
HC Sample	n/a		5.33	ppm	
HC Bckgrd	n/a		3.00	ppm	
CO Sample	32.4	2	31.46	ppm	(Dry)
CO Bckgrd	0.6	2	0.58	ppm	
NOx Sample	n/a		36.64	ppm	(Dry)
NOx Bckgrd	0.2	2	0.20	ppm	
CO2 Sample	48.6	1	0.4612	%	(Wet)
CO2 Bckgrd	4.6	1	0.0418	%	

Corrected Concentrations

HC	2.43	ppm
CO	30.38	ppm
NOx	35.98	ppm
CO2	0.4208	%

Mass Emissions

HC	2.411	grams
CO	60.949	grams
NOx	119.292	grams
Particulate	6.388	grams
CO2	13.265	kg
Fuel	9.27 lb	4.20 kg

Sample Flows

	scfm	scmm
Blower 1 Rate:	3,020.4	85.54
Blower 2 Rate:	0.0	0.00
90 mm System:		
Gas Meter 1:	1.97	0.06
Gas Meter 2:	3.78	0.11
Sample Rate:	1.81	0.05
Total Flow Rate:	3,022.17	85.59

Particulate Data

Filter Number:	2325.0-26 (pair)	
Weight Gain:	3.820	mg
Sample Multiplier:	1.672	

Correction Factors

NOx Humidity CF:	1.006
Dry-to-Wet CF, Sample:	0.987
Dry-to-Wet CF, Bckgrd:	0.991
Dilution Factor:	29.19

Test Cycle Data

Sample Time:	1,207.90	sec		
Work:	24.97	hp-hr	18.62	kW-hr
Reference Work:	24.83	hp-hr	18.52	kW-hr
Total Volume (Vmix):	60,841.4	scf	1,723.06	scm

Brake-Specific Emission Results

BSHC (Cell)	0.097	g/hp-hr	0.129	g/kW-hr
CO	2.441	g/hp-hr	3.273	g/kW-hr
NOx (Cell)	4.777	g/hp-hr	6.407	g/kW-hr
Particulate	0.256	g/hp-hr	0.343	g/kW-hr
CO2	531.3	g/hp-hr	712.42	g/kW-hr
BSFC	0.371	lb/hp-hr	0.226	kg/kW-hr

Southwest Research Institute - Department of Emissions Research
EPA Hot Transient Emission Test Results
Project No. 08-2062-004

Engine Model:	91 DDC Series 60	Test No.: ONHWY-HOT-1	DIESEL ONHWY, EM-2677-F
Engine Desc.:	12.7 L (775 CID) 6	Date: 03/31/1999 Time: 03:00	HCR: 1.812 FID Resp: 1.00
Engine Cycle:	Diesel	Program HDT: 4.04-R	H= 0.132 C= 0.868 O= 0.000 X= 0.000
Engine S/N:	6RE001123	Cell: 4 Bag Cart: 2	

Ambient/Test Cell Conditions

Barometer:	28.97 in Hg	98.1 kPa	
Engine Inlet Air			
Temperature:	74.0 °F	23.3 °C	
Dew Point:	59.2 °F	15.1 °C	
Abs. Humidity:	77.9 gr/lb	11.1 g/kg	
Rel. Humidity:	60 %		
Dilution Air:			
Temperature:	78.0 °F	25.6 °C	
Abs. Humidity	68.9 gr/lb	9.8 g/kg	
Rel. Humidity:	47 %		

Measured Gaseous Data

	Meter	Range	Concentration		
HC Sample	n/a		5.61	ppm	
HC Bckgrd	n/a		2.80	ppm	
CO Sample	31.2	2	30.29	ppm	(Dry)
CO Bckgrd	0.7	2	0.68	ppm	
NOx Sample	n/a		35.14	ppm	(Dry)
NOx Bckgrd	1.1	1	0.28	ppm	
CO2 Sample	49.5	1	0.4701	%	(Wet)
CO2 Bckgrd	6.7	1	0.0610	%	

Corrected Concentrations

HC	2.91	ppm
CO	28.92	ppm
NOx	34.17	ppm
CO2	0.4112	%

Mass Emissions

HC	2.909	grams
CO	58.558	grams
NOx	114.527	grams
Particulate	5.188	grams
CO2	13.086	kg
Fuel	9.14 lb	4.15 kg

Sample Flows

	scfm	scmm
Blower 1 Rate:	3,050.1	86.38
Blower 2 Rate:	0.0	0.00
90 mm System:		
Gas Meter 1:	1.98	0.06
Gas Meter 2:	3.78	0.11
Sample Rate:	1.80	0.05
Total Flow Rate:	3,051.94	86.43

Particulate Data

Filter Number:	2234.0-1 (pair)	
Weight Gain:	3.063	mg
Sample Multiplier:	1.694	

Correction Factors

NOx Humidity CF:	1.007
Dry-to-Wet CF, Sample:	0.980
Dry-to-Wet CF, Bckgrd:	0.984
Dilution Factor:	28.65

Test Cycle Data

Sample Time:	1,207.50	sec		
Work:	24.85	hp-hr	18.53	kW-hr
Reference Work:	24.84	hp-hr	18.52	kW-hr
Total Volume (Vmix):	61,420.4	scf	1,739.46	scm

Brake-Specific Emission Results

BSHC (Cell)	0.117	g/hp-hr	0.157	g/kW-hr
CO	2.356	g/hp-hr	3.160	g/kW-hr
NOx (Cell)	4.609	g/hp-hr	6.180	g/kW-hr
Particulate	0.209	g/hp-hr	0.280	g/kW-hr
CO2	526.6	g/hp-hr	706.19	g/kW-hr
BSFC	0.368	lb/hp-hr	0.224	kg/kW-hr

Southwest Research Institute - Department of Emissions Research
EPA Hot Transient Emission Test Results
Project No. 08-2062-004

Engine Model:	91 DDC Series 60	Test No.: ONHWY-HOT-2	DIESEL ONHWY, EM-2677-F
Engine Desc.:	12.7 L (775 CID) 6	Date: 03/31/1999 Time: 03:40	HCR: 1.812 FID Resp: 1.00
Engine Cycle:	Diesel	Program HDT: 4.04-R	H= 0.132 C= 0.868 O= 0.000 X= 0.000
Engine S/N:	6RE001123	Cell: 4 Bag Cart: 2	

Ambient/Test Cell Conditions

Barometer:	28.96 in Hg	98.1 kPa	
Engine Inlet Air			
Temperature:	74.0 °F	23.3 °C	
Dew Point:	57.9 °F	14.4 °C	
Abs. Humidity:	74.3 gr/lb	10.6 g/kg	
Rel. Humidity:	57 %		
Dilution Air:			
Temperature:	78.0 °F	25.6 °C	
Abs. Humidity	69.0 gr/lb	9.9 g/kg	
Rel. Humidity:	47 %		

Measured Gaseous Data

	Meter	Range	Concentration		
HC Sample	n/a		5.71	ppm	
HC Bckgrd	n/a		2.80	ppm	
CO Sample	31.4	2	30.48	ppm	(Dry)
CO Bckgrd	0.7	2	0.68	ppm	
NOx Sample	n/a		35.46	ppm	(Dry)
NOx Bckgrd	1.2	1	0.31	ppm	
CO2 Sample	49.7	1	0.4721	%	(Wet)
CO2 Bckgrd	6.1	1	0.0555	%	

Corrected Concentrations

HC	3.01	ppm
CO	29.10	ppm
NOx	34.46	ppm
CO2	0.4185	%

Mass Emissions

HC	3.000	grams
CO	58.749	grams
NOx	114.052	grams
Particulate	5.113	grams
CO2	13.278	kg
Fuel	9.28 lb	4.21 kg

Sample Flows

	scfm	scmm
Blower 1 Rate:	3,041.5	86.14
Blower 2 Rate:	0.0	0.00
90 mm System:		
Gas Meter 1:	1.97	0.06
Gas Meter 2:	3.78	0.11
Sample Rate:	1.81	0.05
Total Flow Rate:	3,043.27	86.19

Particulate Data

Filter Number:	2235.0-2 (pair)	
Weight Gain:	3.043	mg
Sample Multiplier:	1.680	

Correction Factors

NOx Humidity CF:	0.998
Dry-to-Wet CF, Sample:	0.980
Dry-to-Wet CF, Bckgrd:	0.984
Dilution Factor:	28.53

Test Cycle Data

Sample Time:	1,207.20	sec		
Work:	24.84	hp-hr	18.52	kW-hr
Reference Work:	24.83	hp-hr	18.52	kW-hr
Total Volume (Vmix):	61,230.6	scf	1,734.09	scm

Brake-Specific Emission Results

BSHC (Cell)	0.121	g/hp-hr	0.162	g/kW-hr
CO	2.365	g/hp-hr	3.172	g/kW-hr
NOx (Cell)	4.591	g/hp-hr	6.157	g/kW-hr
Particulate	0.206	g/hp-hr	0.276	g/kW-hr
CO2	534.5	g/hp-hr	716.82	g/kW-hr
BSFC	0.373	lb/hp-hr	0.227	kg/kW-hr

Southwest Research Institute - Department of Emissions Research
EPA Hot Transient Emission Test Results
Project No. 08-2062-004

Engine Model:	91 DDC Series 60	Test No.: ONHWY-HOT-3	DIESEL ONHWY, EM-2677-F
Engine Desc.:	12.7 L (775 CID) 6	Date: 04/02/1999 Time: 02:10	HCR: 1.812 FID Resp: 1.00
Engine Cycle:	Diesel	Program HDT: 4.04-R	H= 0.132 C= 0.868 O= 0.000 X= 0.000
Engine S/N:	6RE001123	Cell: 4 Bag Cart: 2	

Ambient/Test Cell Conditions

Barometer:	28.83	in Hg	97.6 kPa
Engine Inlet Air			
Temperature:	73.0	°F	22.8 °C
Dew Point:	61.7	°F	16.5 °C
Abs. Humidity:	85.7	gr/lb	12.2 g/kg
Rel. Humidity:	68	%	
Dilution Air:			
Temperature:	81.0	°F	27.2 °C
Abs. Humidity	101.9	gr/lb	14.6 g/kg
Rel. Humidity:	62	%	

Measured Gaseous Data

	Meter	Range	Concentration		
HC Sample	n/a		6.71	ppm	
HC Bckgrd	n/a		3.75	ppm	
CO Sample	33.0	2	32.05	ppm	(Dry)
CO Bckgrd	0.5	2	0.49	ppm	
NOx Sample	n/a		35.23	ppm	(Dry)
NOx Bckgrd	0.3	2	0.30	ppm	
CO2 Sample	49.6	1	0.4711	%	(Wet)
CO2 Bckgrd	5.4	1	0.0491	%	

Corrected Concentrations

HC	3.09	ppm
CO	30.66	ppm
NOx	33.98	ppm
CO2	0.4237	%

Mass Emissions

HC	3.073	grams	
CO	61.694	grams	
NOx	115.531	grams	
Particulate	5.286	grams	
CO2	13.398	kg	
Fuel	9.36 lb	4.25	kg

Sample Flows

	scfm	scmm
Blower 1 Rate:	3,029.7	85.80
Blower 2 Rate:	0.0	0.00
90 mm System:		
Gas Meter 1:	1.96	0.06
Gas Meter 2:	3.77	0.11
Sample Rate:	1.81	0.05
Total Flow Rate:	3,031.47	85.85

Particulate Data

Filter Number:	2264.0-14 (pair)	
Weight Gain:	3.150	mg
Sample Multiplier:	1.678	

Correction Factors

NOx Humidity CF:	1.029
Dry-to-Wet CF, Sample:	0.973
Dry-to-Wet CF, Bckgrd:	0.977
Dilution Factor:	28.57

Test Cycle Data

Sample Time:	1,207.90	sec		
Work:	24.87	hp-hr	18.55	kW-hr
Reference Work:	24.83	hp-hr	18.52	kW-hr
Total Volume (Vmix):	61,028.6	scf	1,728.37	scm

Brake-Specific Emission Results

BSHC (Cell)	0.124	g/hp-hr	0.166	g/kW-hr
CO	2.481	g/hp-hr	3.327	g/kW-hr
NOx (Cell)	4.645	g/hp-hr	6.230	g/kW-hr
Particulate	0.213	g/hp-hr	0.285	g/kW-hr
CO2	538.7	g/hp-hr	722.41	g/kW-hr
BSFC	0.376	lb/hp-hr	0.229	kg/kW-hr

Southwest Research Institute - Department of Emissions Research
EPA Hot Transient Emission Test Results
Project No. 08-2062-004

Engine Model:	91 DDC Series 60	Test No.: ONHWY-HOT-4	DIESEL ONHWY, EM-2677-F
Engine Desc.:	12.7 L (775 CID) 6	Date: 04/02/1999 Time: 02:50	HCR: 1.812 FID Resp: 1.00
Engine Cycle:	Diesel	Program HDT: 4.04-R	H= 0.132 C= 0.868 O= 0.000 X= 0.000
Engine S/N:	6RE001123	Cell: 4 Bag Cart: 2	

Ambient/Test Cell Conditions

Barometer:	28.84	in Hg	97.7 kPa
Engine Inlet Air			
Temperature:	73.0	°F	22.8 °C
Dew Point:	59.2	°F	15.1 °C
Abs. Humidity:	78.2	gr/lb	11.2 g/kg
Rel. Humidity:	62	%	
Dilution Air:			
Temperature:	80.0	°F	26.7 °C
Abs. Humidity	97.8	gr/lb	14.0 g/kg
Rel. Humidity:	61	%	

Measured Gaseous Data

	Meter	Range	Concentration		
HC Sample	n/a		6.92	ppm	
HC Bckgrd	n/a		4.30	ppm	
CO Sample	32.1	2	31.17	ppm	(Dry)
CO Bckgrd	0.6	2	0.58	ppm	
NOx Sample	n/a		35.40	ppm	(Dry)
NOx Bckgrd	0.4	2	0.40	ppm	
CO2 Sample	49.9	1	0.4741	%	(Wet)
CO2 Bckgrd	6.0	1	0.0546	%	

Corrected Concentrations

HC	2.77	ppm
CO	29.72	ppm
NOx	34.08	ppm
CO2	0.4214	%

Mass Emissions

HC	2.759	grams
CO	59.911	grams
NOx	113.803	grams
Particulate	5.216	grams
CO2	13.348	kg
Fuel	9.33 lb	4.23 kg

Sample Flows

	scfm	scmm
Blower 1 Rate:	3,035.4	85.97
Blower 2 Rate:	0.0	0.00
90 mm System:		
Gas Meter 1:	1.99	0.06
Gas Meter 2:	3.75	0.11
Sample Rate:	1.76	0.05
Total Flow Rate:	3,037.19	86.02

Particulate Data

Filter Number:	2268.0-15 (pair)	
Weight Gain:	3.021	mg
Sample Multiplier:	1.726	

Correction Factors

NOx Humidity CF:	1.008
Dry-to-Wet CF, Sample:	0.974
Dry-to-Wet CF, Bckgrd:	0.978
Dilution Factor:	28.40

Test Cycle Data

Sample Time:	1,207.70	sec		
Work:	24.85	hp-hr	18.53	kW-hr
Reference Work:	24.83	hp-hr	18.52	kW-hr
Total Volume (Vmix):	61,133.6	scf	1,731.34	scm

Brake-Specific Emission Results

BSHC (Cell)	0.111	g/hp-hr	0.149	g/kW-hr
CO	2.411	g/hp-hr	3.233	g/kW-hr
NOx (Cell)	4.580	g/hp-hr	6.141	g/kW-hr
Particulate	0.210	g/hp-hr	0.281	g/kW-hr
CO2	537.1	g/hp-hr	720.31	g/kW-hr
BSFC	0.375	lb/hp-hr	0.228	kg/kW-hr

APPENDIX N-2

DDC Series 60 Steady-State Test Data

DDC SERIES 60 STEADY-STATE TEST RESULTS

						Emissions (g/hr)				Fuel	BS Emissions (g/hp-hr)				BSFC
Fuel	**Mode**	**Run #**	**rpm**	**lb-ft**	**hp**	**HC**	**CO**	**NOx**	**PM**	**(lb/hr)**	**HC**	**CO**	**NOx**	**PM**	**(lb/hp-hr)**
CARB	Idle	1	600	2	1.2	0.11	19.7	75.8	5.03	2.6	NA	NA	NA	NA	NA
CARB	Idle	2	600	0	0.8	1.34	21.0	60.3	3.27	2.3	NA	NA	NA	NA	NA
CARB	Idle	3	600	0	0.4	1.16	20.2	64.5	2.75	2.3	NA	NA	NA	NA	NA
CARB	Idle	4	600	0	0.1	0.11	18.5	60.2	3.16	2.4	NA	NA	NA	NA	NA
CARB	Idle	5	600	0	0.1	1.14	22.0	66.0	3.35	2.6	NA	NA	NA	NA	NA
CARB	N5	1	1706	536	174.2	8.32	49.5	1627.5	13.61	57.9	0.048	0.28	9.34	0.078	0.332
CARB	N5	2	1695	536	172.6	9.08	48.9	1592.2	12.44	56.1	0.053	0.28	9.22	0.072	0.325
CARB	N5	3	1714	542	177.6	6.70	58.8	1603.6	11.42	57.5	0.038	0.33	9.03	0.064	0.324
CARB	N5	4	1718	543	179.0	6.98	57.0	1617.3	11.93	58.2	0.039	0.32	9.04	0.067	0.325
CARB	N5	5	1720	544	180.0	8.75	50.5	1645.8	12.82	58.6	0.049	0.28	9.14	0.071	0.326
CARB	N8	1	1800	1042	358.0	12.65	168.6	2623.7	25.15	114.1	0.035	0.47	7.33	0.070	0.319
CARB	N8	2	1800	1059	362.3	11.24	175.9	2581.8	19.80	114.1	0.031	0.49	7.13	0.055	0.315
CARB	N8	3	1800	1056	362.4	10.11	207.3	2807.8	27.25	121.5	0.028	0.57	7.75	0.075	0.335
CARB	N8	4	1800	1053	360.1	10.53	185.9	2608.4	19.18	113.3	0.029	0.52	7.24	0.053	0.315
CARB	N8	5	1800	1052	360.4	9.34	189.4	2598.4	19.49	114.4	0.026	0.53	7.21	0.054	0.317
CARB	N8	6	1800	1055	364.0	10.04	185.8	2604.3	19.06	114.9	0.028	0.51	7.15	0.052	0.316
CARB	N8	7	1800	1051	364.0	12.02	189.6	2653.9	19.08	114.7	0.033	0.52	7.29	0.052	0.315
ONHWY	Idle	1	600	0	0.1	4.39	28.5	52.5	3.64	2.1	NA	NA	NA	NA	NA
ONHWY	Idle	2	600	0	0.7	3.98	30.7	64.8	6.07	2.3	NA	NA	NA	NA	NA
ONHWY	N5	1	1700	531	171.8	10.00	50.2	1684.6	13.38	55.5	0.058	0.29	9.81	0.078	0.323
ONHWY	N5	2	1699	530	171.2	11.91	50.9	1681.4	13.21	55.8	0.070	0.30	9.82	0.077	0.326
ONHWY	N8	1	1800	1059	362.8	12.01	185.4	2697.0	24.29	116.6	0.033	0.51	7.43	0.067	0.321
ONHWY	N8	2	1800	1060	363.1	12.64	191.4	2687.5	23.18	115.9	0.035	0.53	7.40	0.064	0.319
NONRD	Idle	1	600	0	0.4	2.47	34.1	61.1	7.41	2.4	NA	NA	NA	NA	NA
NONRD	Idle	2	600	0	1.3	3.41	31.4	64.4	4.57	2.4	NA	NA	NA	NA	NA
NONRD	N5	1	1718	538	175.9	3.51	53.0	1726.3	21.43	56.5	0.020	0.30	9.81	0.122	0.321
NONRD	N5	2	1701	532	171.6	11.66	51.1	1766.2	22.69	55.9	0.068	0.30	10.29	0.132	0.326
NONRD	N8	1	1800	1093	373.9	6.02	207.4	2811.9	35.82	116.1	0.016	0.55	7.52	0.096	0.311
NONRD	N8	2	1800	1099	376.0	11.31	194.9	2907.5	31.88	119.4	0.030	0.52	7.73	0.085	0.318

AAR 3-mode Duty-Cycle Weighted Results

	bsfc	HC	CO	NOx	PM
CARB Run #1	0.331	0.040	0.482	8.236	0.091
CARB Run #2	0.326	0.043	0.497	8.005	0.072
CARB Run #3	0.339	0.035	0.567	8.396	0.082
CARB Run #4	0.327	0.033	0.519	8.059	0.069
CARB Run #5	0.330	0.038	0.525	8.095	0.072
Average	**0.331**	**0.038**	**0.518**	**8.158**	**0.077**
COV	2%	10%	6%	2%	12%
On-Hwy Run #1	0.330	0.058	0.547	8.389	0.084
On-Hwy Run #2	0.329	0.061	0.567	8.397	0.091
Average	**0.329**	**0.059**	**0.557**	**8.393**	**0.087**
COV	0%	4%	3%	0%	5%
Nonroad Run #1	0.322	0.026	0.597	8.464	0.131
Nonroad Run #2	0.327	0.054	0.561	8.729	0.116
Average	**0.325**	**0.040**	**0.579**	**8.596**	**0.123**
COV	1%	49%	4%	2%	9%
carb vs nonroad	2%	-6%	-11%	-5%	-37%
on-hwy vs nonroad	1%	47%	-4%	-2%	-29%
carb vs on-hwy	0%	-36%	-7%	-3%	-11%

APPENDIX O

Particulate Size Characterization

SOUTHWEST RESEARCH INSTITUTE
P.O. Drawer 28510
San Antonio, Texas 78228-0510

LOCOMOTIVE FUEL EFFECTS STUDY: PARTICULATE SIZE CHARACTERIZATION

By

Steven G. Fritz
E. Robert Fanick

FINAL REPORT

Prepared for

CALIFORNIA AIR RESOURCES BOARD
STATIONARY SOURCE DIVISION - FUELS SECTION
P.O. BOX 2815
SACRAMENTO, CA 95814

JANUARY 2000

Reviewed:

Terry L. Ullman, Manager
Department of Emissions Research
Automotive Products and
Emissions Research Division

Approved:

Charles T. Hare, Director
Department of Emissions Research
Automotive Products and
Emissions Research Division

SwRI 08.02062.003

LOCOMOTIVE FUEL EFFECTS STUDY: PARTICULATE SIZE CHARACTERIZATION

By

Steven G. Fritz
E. Robert Fanick

FINAL REPORT

Prepared For

CALIFORNIA AIR RESOURCES BOARD
STATIONARY SOURCE DIVISION - FUELS SECTION
P.O. BOX 2815
SACRAMENTO, CA 95814

JANUARY 2000

FOREWORD

This project was performed for the California Air Resources Board (ARB) under SwRI Project 08-02062-003. The technical representative for ARB was Mr. Tony Brasil, Stationary Source Division - Fuels Section. The Principal Investigator was Mr. E. Robert Fanick, Senior Research Scientist, and the Project Manager for this work was Mr. Steven G. Fritz, Senior Research Engineer, both in the Department of Emissions Research. Mr. Michael J. Dammann, Group Leader in the Chemistry and Chemical Engineering Division, was responsible for the elemental analyses. SwRI technical personnel involved in engine operation, emissions sampling, and emissions analysis included Messrs. C. Eddie Grinstead, William L. Shackelford, and Ernesto San Miguel, all in the Department of Emissions Research. Ms. Yolanda Rodriguez and Ms. Kelley L. Strate performed the chemical analysis. Data reduction was performed by Ms. Kathleen M. Jack, Ms. Deborah A. Liston, and Ms. Sylvia G. Nino, also all in the Department of Emissions Research.

TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

AAR	Association of American Railroads
ARB	California Air Resources Board
API	American Petroleum Institute
ASTM	American Society for Testing and Materials
BTU	British Thermal Unit
°C	degrees Centigrade
cc	cubic centimeter
CFR	Code of Federal Regulations
cSt	centistokes
DFI/GC™	direct filter injection, gas chromatography
EMD	Electro-Motive Division of General Motors Corporation
EP	end point
EPA	U.S. Environmental Protection Agency
°F	degrees Fahrenheit
FID	flame ionization detector
FTP	Federal Test Procedure
g	gram
gal	gallon
GE	Transportation Systems Division of the General Electric Company
H_2O	water
hp	horsepower
hr	hour
IBP	initial boiling point
IC	Ion Chromatography
ICP/MS	inductively-coupled plasma/mass spectroscopy
in	inch
L	liters
lb	pound
min	minute
mm	millimeter
MOUDI	micro-orifice uniform deposition impactor
NIST	National Institute of Standards and Technology
OEM	original equipment manufacturer
PM	particulate matter
ppm	parts per million
sec	seconds
SOF	soluble organic fraction
SwRI	Southwest Research Institute
UP	Union Pacific Railroad
VOF	volatile organic fraction
wt	weight
%	percent
Fm	micrometer (1×10^{-6} meter), micron

EXECUTIVE SUMMARY

This report documents results from exhaust particulate size distribution measurements performed on a 4,400 hp General Electric model DASH9-44CW diesel locomotive engine. This locomotive (UP No. 9724) was one of six locomotives tested for the California Air Resources Board (ARB) as part of a fuel effects study.

For the particulate size determination work reported herein, two fuels were compared; CARB diesel and a nonroad diesel fuel with a fuel sulfur level of 0.3 percent (3,190 ppm). These fuels were two of the four fuels used in the ARB locomotive fuel effects study. Tests were run at only two operating conditions: Idle and Notch 8 (rated power). Particle size distribution was measured using a Model 110 micro-orifice uniform deposit impactor (MOUDI). Additional analysis of the size-segregated particulate included determination of the volatile organic fraction (VOF), elemental analysis, and anion and cation analyses.

Less than one percent of the particulate for both fuels was larger than 2.5 Fm ($PM_{2.5}$), at both Idle and Notch 8. As expected, the total particulate mass rate was higher with the 0.3 percent sulfur nonroad diesel fuel at both operating conditions. One significant finding of this study was that the PM mass emission rates were similar for both fuels down to a particle size of 0.17 Fm. Most of the difference in total PM observed between the two fuels occurred in the smaller size ranges, 0.17 Fm to 0.09 Fm, 0.09 Fm to 0.056 Fm, and less than 0.056 Fm, where the 0.3 percent sulfur fuel had significantly higher mass emission rates. Subsequent analysis of the PM samples showed that the increased PM at the smaller size fractions was largely attributed to fuel-derived portion of the VOF and to sulfate emissions. Another interesting finding from this study was that for both fuels, the particle size distribution at Idle was monomodal, and at Notch 8 it was bimodal.

An elemental analysis was performed on selected size ranges, and only five elements detectable by XRF were present in enough quantity to be above detection limits. These elements were barium, manganese, nickel, sulfur, and zinc. The various metal elements were mostly attributed to engine wear metals, and the sulfur came from the fuel and lubricating oil. Except for sulfur, the metal elements contributed only a small fraction to the total particulate mass. At both Idle and Notch 8, most elements detected were in the 0.54 Fm to 0.31 Fm, 0.31 Fm to 0.17 Fm, and 0.17 Fm to 0.09 Fm particle size ranges.

For the anions and cations analyzed, sulfate was detected at the highest mass emission rates, especially with the higher sulfur fuel. Chloride, nitrate, and potassium ions were detected, but contributed only a small fraction to the total particulate mass.

I. INTRODUCTION AND BACKGROUND

This project was an experimental program intended to characterize the size distribution of exhaust particles from a locomotive engine. Particulate characterization by particle size included the volatile organic carbon content, elemental analysis, and anion and cation mass emission rates. The work was performed to determine the particulate composition and how the particulate characteristics change in relation to the size of particle. Exhaust emission and fuel consumption measurements were performed using a 4,400 hp, General Electric (GE), model DASH9-44CW locomotive, provide by Union Pacific Railroad (UP).

The EPA definition of an engine exhaust particulate is any material collected on a fluorocarbon-coated glass fiber or fluorocarbon-based (membrane) filter, from a dilute exhaust stream, at a sample zone temperature less than 52EC (125EF). For particulate measurement, the engine's raw exhaust is typically diluted in a tunnel, which is generally about 8 to 18 inches in diameter and about 20 feet long. The dilution ratio generally ranges from 2:1 to 20:1, depending on engine operating conditions, tunnel air flow capacity, and system control characteristics required to meet the sample zone temperature requirements. For a given engine, the number and size of particles in the exhaust are functions of many variables including the sample probe location in the plume. The predominant size range in terms of total mass is larger than 0.1 micron, and in terms of number of particles, the predominant size is below 0.1 micron. The dependence of particle size and number on sample probe location is directly related to the temperature, dilution, and "age" of the particles. As engine exhaust cools, the higher molecular weight gaseous hydrocarbons begin to condense into aerosols, the particles tend to agglomerate, and adsorption of hydrocarbons may occur. Each mechanism results in larger and heavier particles.

In this study, the aerodynamic diameter is defined as the diameter of a unit density sphere (1 g/cc) having the same settling speed in air as the measured particle. Sizing devices such as cascade impactors use aerodynamic principles to size particles. In an impactor, a sample containing particles with a mixture of shapes and densities is fractionated and collected according to aerodynamic characteristics. As the sample stream passes through stages in the impactor with apertures of decreasing width or diameter, flow is accelerated and progressively smaller particles collect on impaction plates. Particles which are aerodynamically equivalent in size to the unit density spheres are collected on specific stages, calibrated under similar conditions. The mass collected on each stage indicates the percentage of particles within a specific aerodynamic diameter range.

II. TECHNICAL APPROACH

Testing was performed at the Southwest Research Institute (SwRI) Locomotive Exhaust Emissions Test Center in San Antonio, Texas. This unique facility was established in 1993 in cooperation with the Association of American Railroads (AAR), and is the only non-original equipment manufacturer (non-OEM) facility capable of performing locomotive exhaust emission tests.

Presented below is an overview of the technical approach used to conduct locomotive exhaust emissions testing for this study. A description of the locomotive selected for testing, engine power measurement, fuel consumption measurement, the test fuels used in this program, exhaust emissions test procedures, and particulate measurement procedures are also included. Analytical procedures for particulate characterization are included in Section III of this report.

A. Test Locomotive

Exhaust particulate size distribution measurements were performed on a General Electric (GE) model DASH9-44CW diesel locomotive engine. This locomotive, UP No. 9724, was one of six locomotives tested for the California Air Resources Board (ARB) as part of a fuel effects study. UP No. 9724 was manufactured in July 1994, and has the serial number 47870. It was equipped with a 4,400 hp, GE model 7FDL16N62, turbocharged diesel engine (SN 970815R), which was remanufactured by GE in August 1997.

B. Engine Power Measurement

Most line-haul locomotives are equipped with the "dynamic brake" feature in which the electric motors used for traction are reverse-excited to become generators to slow the train. The electrical power generated is dissipated in resistance grids. Those locomotives with the self-load feature can dissipate the main alternator power into these "dynamic brake" resistance grids. UP. No. 9724 was equipped with resistance load grids that were capable of loading the engine to its full power level of 4,400 hp.

The goal of power measurements was to compute the net engine power produced to perform work, referred to as flywheel or “gross” power. Gross power for the GE locomotive was recorded from the on-board computer display. Gross power represents the sum of “traction power” plus “auxiliary power.”

C. Fuel Consumption Measurement

Diesel fuel consumption rate was measured on a mass basis, using a mass flow meter adapted from laboratory use at SwRI. The system was equipped with a heat exchanger to control fuel supply temperature to 90±10°F. Hot return fuel from the engine that normally returns to the locomotive fuel tank was cooled before returning to the fuel measurement reservoir ("day" tank) to assure consistent fuel supply temperature to the engine.

D. Test Fuels

Two fuels were used for this particulate characterization study. The first fuel was a 0.3 percent sulfur nonroad diesel fuel, with an aromatic level of about 40 percent and a cetane number of 44.5. The second fuel was a blend of two commercially available CARB diesel fuels with a sulfur level of 50 ppm (0.005 percent) and an aromatic content of 22 percent by volume. This fuel consisted of 8,000 gallons of commercially available CARB-approved diesel fuel from the Texaco refinery in Los Angeles, California plus another 8,000 gallons of commercially-available CARB-approved diesel fuel from the ARCO refinery in South Gate, California. Each fuel was delivered to the SwRI Locomotive Exhaust Emissions Test Center by truck and the fuels were mixed in a single railroad tank car. Table 1 gives selected properties for the two fuels. Table 2 gives the results of a metals analysis of the two fuels.

E. Regulated Exhaust Emissions Test Procedure

SwRI used the Federal Test Procedure (FTP) for locomotives as detailed in 40 CFR Part 92, Subpart B as the basis for emission measurement techniques. For this study, two throttle notch settings were used: Idle and Notch 8.

Particulate emissions were measured at each test point using a "split then dilute" technique, in which a portion of the raw locomotive exhaust was “split” off of the total flow and mixed with filtered air in a 10-inch diameter dilution tunnel. The split sample was transferred to the dilution tunnel through a 2-inch diameter stainless steel tube that was insulated and electrically heated to 375°F. This dilution tunnel was located at ground level, next to the locomotive, as shown in Figure 1. Particulate samples from the dilute exhaust were collected using an isokinetic sampling probe shown in Figure 2.

Before emission testing was started, the engine was first brought to operating temperature. This procedure involved operating the locomotive at Notch 8 for at least 15 minutes. After the warm-up period, testing began with Idle using the 0.3 percent sulfur fuel. Four consecutive repeat tests were performed to collect sufficient samples for the various analytical procedures. The engine was then brought to Notch 8, and the sequence of four consecutive tests was repeated. After a fuel change to the CARB diesel, the sampling sequence was repeated at Idle and Notch 8.

TABLE 1. SELECTED PROPERTIES OF THE TWO LOCOMOTIVE TEST FUELS

Determinations	ASTM Test Method	CARB Diesel EM-2663-F	0.3% Sulfur Nonroad Diesel EM-2708-F	EPA Locomotive Spec. [a]
API Gravity @ 60°F	D4052	39.1	34.1	32 - 37
specific gravity		0.8295	0.8547	ns
density (lb/gal)		6.92	7.13	ns
Viscosity @ 40EC (cSt)	D445-83	2.46	2.77	2.0 - 3.2
Sulfur (Wt%)	D2622-94	0.005	0.319	0.2 - 0.4
Cetane Index	D976	52.0	46.5	40 - 48
Cetane Index	D4737	53.1	46.6	ns
Cetane Number	D613-84	51.0	44.5	40 - 48
Nitrogen Content (ppm)	D4629-96	8.4	220.1	ns
Heat of Combustion	D240			
Gross (BTU/lb)		19,715	19,440	ns
Net (BTU/lb)		18,479	18,240	ns
Gross (BTU/gal)		136,400	138,600	ns
Net (btu/gal)		127,900	130,100	ns
Carbon-Hydrogen Ratio	D3178			
% Carbon		86.37	86.77	ns
% Hydrogen		13.63	13.23	ns
Hydrogen/Carbon Ratio		1.880	1.818	ns
SFC Aromatics	D5186-96			
Total Mass %		22.39	33.11	27 min.
PNA Mass %		1.66	8.89	
Hydrocarbon Type	D1319-84			
Aromatics (%)		22.4	39.8	ns
Olefins (%)		2.0	2.5	ns
Saturates (%)		75.6	57.7	ns
Flash Point (°F)	D93-80	167	166	130 min.
Distillation	D86-96			
	% Recovered	Temp. °F	Temp. °F	Temp. °F
	IBP	368	375	340 - 400
	10	413	426	400 - 460
	50	490	513	470 - 540
	90	606	620	560 - 630
	EP	659	672	610 - 690

Note: a - Diesel fuel for locomotive testing as specified by EPA in 40 CFR 92, §92.113, Table B113-1.
ns - not specified

TABLE 2. TEST FUEL METALS ANALYSIS RESULTS

Element	ASTM Test Method	CARB Diesel EM-2663-F	0.3% Sulfur Nonroad Diesel EM-2708-F
Fuel Metals Analysis			
Antimony, ppm	D5185	<1	<1
Arsenic, ppm		<5	<5
Beryllium, ppm		<2.5	<5
Cadmium, ppm		<1	<1
Chromium, ppm		<1	<1
Cobalt, ppm		<2.5	<5
Copper, ppm		<1	<1
Lead, ppm		<1	1
Manganese, ppm		<1	<1
Mercury, ppm		<5	<5
Nickel, ppm		<1	<1
Selenium, ppm		<5	<5

FIGURE 1. EMISSIONS TEST SETUP USED FOR SAMPLING PARTICULATE

FIGURE 2. ISOKINETIC PARTICULATE SAMPLE PROBE USED WITHIN DILUTION TUNNEL FOR PARTICLE SIZING MEASUREMENTS

III. DESCRIPTION OF ANALYTICAL METHODS

This section of the report describes the analytical methods used for assessing particle size distribution of particulate emissions, and the subsequent chemical characterization of the particulate collected.

A. MOUDI for Particle Size Distribution

Particle size distribution was measured using a Model 110 micro-orifice uniform deposit impactor (MOUDI) with an isokinetic sampling probe located within the dilution tunnel. The sample flow rate through the MOUDI was 30 L/min. Nine MOUDI stages were used to collect particulate having particle diameter cut-off of ranges of greater than 6.2 Fm, 3.1 to 6.2 Fm, 1.8 to 3.1 Fm, 1.0 to 1.8 Fm, 0.54 to 1.0 Fm, 0.31 to 0.54 Fm, 0.17 to 0.31 Fm, 0.09 to 0.17 Fm, and 0.056 to 0.09 Fm. The last stage was followed by a 47 mm Pallflex T60A20 backup filter to collect particles below 0.056 Fm. Figure 3 shows the MOUDI installed at the locomotive test center.

FIGURE 3. MOUDI PARTICLE SIZE SYSTEM USED AT LOCOMOTIVE TEST CENTER

The MOUDI operating principal is the same as any inertial cascade impactor with multiple nozzles. At each stage, jets of particle-laden dilute exhaust impinge upon an impaction plate. Particles larger than the mean diameter cut-size of that stage have inertia sufficient to cross the air streamlines to impact the plate. Upon contact with the plate, the particles remain on the impaction plate. Smaller particles have less inertia, cannot cross the streamlines, and proceed to the next stage. Smaller nozzles, with higher air velocity, are used to separate finer particles. The process continues through the cascade impactor until particles smaller than the last stage collection capability are collected on the final glass fiber backup filter. By rotating every other stage of the impactor and holding the others stationary, every nozzle plate rotates relative to its impaction plate. This relative rotation allows the MOUDI to achieve near uniform particle deposition on the impaction plates. Figure 4 shows particulate collected on one of the impaction plates of a MOUDI stage.

FIGURE 4. PARTICULATE COLLECTED ON ONE OF THE IMPACTION PLATES OF A MOUDI STAGE

For gravimetric particle size distribution and for the volatile organic fraction (VOF) determinations, uncoated aluminum foil plates were used to collect samples. These foils are the typical collection media used for the MOUDI system. Nucleopore substrates were used in place of the aluminum foil plates to collect samples for subsequent characterization of metals, cations, and anions. In all, four runs at each operating condition were performed. Run 1 used standard uncoated 47-mm aluminum foil plates to accumulate particulate. These filters were used for gravimetric mass determination. Run 2 also used uncoated 47-mm aluminum foil

plates. These plates were used to replicate data for gravimetric mass determination, and were then used to determine the volatile organic fraction (VOF) of the collected particulate. Run 3 used 47-mm Nucleopore filter media as plates, in place of the conventional aluminum foils. These filters were used for subsequent elemental analysis, as described below in Section III.C. Run 4 used a second set of 47-mm Nucleopore filter media. These filters were used for subsequent analysis for anions and cations, as described below in Section III.D.

B. DFI/GC for VOF

Direct filter injection gas chromatography (DFI/GC) was used to determine the VOF of the particulate at selected size fractions. VOF is defined in this study as organic material that responds on a flame ionization detector (FID), and has a boiling point of less than approximately 600EF. In addition, the contribution of unburned lubricating oil to VOF was also determined by an interpretive procedure based on simulated distillation boiling point distribution of a lubricating oil sample from the locomotive. The difference between the unburned oil derived VOF and the total VOF is a combination of unburned fuel, oxidized lubricating oil, and oxidized fuel components with a lower boiling temperature than the lubricating oil. For this study, the combination of these lower boiling components will be defined as “fuel-derived VOF”.

Direct DFI/GC processing of the aluminum foil plates was not possible, so the material collected on each foil was transferred to 47-mm Pallflex T60A20 particulate filters for analysis. Lubricating oil from the locomotive was used to quantify the boiling point distribution of unburned lubricating oil contribution to the VOF.

VOF analyses were conducted using a Perkin Elmer Model 8500 gas chromatograph (GC) equipped with a uniquely designed filter injection system and a FID. Pallflex filters containing the samples transferred from the foils were placed into the injector, which was subsequently inserted into a cool zone of the DFI/GC to allow any oxygen in the system to be purged without losing any sample by desorption. When all oxygen had been purged from the system, the injector was pushed into a hot zone of the GC, where the volatile materials were desorbed and deposited into a cool column. A GC temperature program was then used to separate the volatilized compounds by boiling point. These compounds were then detected with a FID.

C. ICP/MS for Elemental Analysis

An inductively coupled plasma, mass spectroscopy (ICP/MS) method was used for determining the elemental content of particulate collected on selected MOUDI plates. Nucleopore filters or plates from individual stages were digested in a mixture of nitric and perchloric acid, followed by digestion with aqua regia. The resulting solution was analyzed by ICP/MS for the elements given in Table 3.

TABLE 3. ELEMENTS STUDIES BY ICP/MS

Aluminum - Al	Antimony - Sb	Arsenic - As
Barium - Ba	Beryllium - Be	Bismuth - Bi
Boron - B	Cadmium - Cd	Calcium - Ca
Chromium - Cr	Cobalt - Co	Copper - Cu
Galium - Ga	Gold - Au	Indium - In
Iron - Fe	Lanthanum - La	Lead - Pb
Lithium - Li	Magnesium - Mg	Manganese - Mn
Mercury - Hg	Molybdenum - Mo	Nickel - Ni
Palladium - Pd	Phosphorus - P	Potassium - K
Ruthenium - Ru	Selenium - Se	Silicon - Si
Silver - Ag	Sodium - Na	Strontium - Sr
Yttrium - Y	Thallium - Tl	Thorium - Th
Tin - Sn	Titanium - Ti	Tungsten - W
Uranium - U	Vanadium - V	Zinc - Zn
Zirconium - Zr		

The ICP/MS instrument was standardized using reference materials that were traceable to the National Institute of Standards and Technology (NIST). Prior to the analysis of any samples, the standardization was also verified with a second NIST traceable reference material. This second standard was from a different lot or manufacturer than the standardization material, and served as a check sample. Immediately after a check sample was run, a blank sample was also run to verify the zero setting of the standardization. The check sample was required to be within the control limits of 90-110 percent recovery of the certified value. The absolute value of the check blank was required to be below the reporting limit for the samples. If either condition was not met, the analysis was terminated and the instrument re-standardized and re-checked. The check sample and check blank were re-run after every ten samples and at the end of the run to ensure that the instrument remained in control throughout the entire run of ten samples. The same control limits were used for the continuing check samples. If a continuing check sample fell out of the control limits, the analysis was terminated, the instrument re-standardized, and all samples processed since the

last compliant check sample were re-run. Detection limits were on the order of 1 to 5 Fg/filter for most elements.

D. IC for Anions and Cations

Anions and cations accumulated on each Nucleopore filter impactor plate were quantified using an ion chromotography (IC) process, where selected stages were extracted by shaking each Nucleopore filter in a solution of 60 percent isopropanol (IPA) and 40 percent water. Analyses of the extracted anions and cations were conducted using an IC equipped with a conductivity detector.

1. Anions -- Sulfate, Nitrate, and Chloride Ions

Sulfuric acid on the filter was converted to ammonium sulfate by exposure to ammonia vapor in a conditioning chamber. The soluble sulfates and other anions were then leached from the filter with a measured volume of 60 percent IPA and 40 percent water. An aliquot of this extract was injected via autosampler into an IC. Anions were separated by analytical column with a dilute solution of sodium bicarbonate and sodium carbonate as the eluent, and then passed through a conductivity detector. The retention time on column provide identification of the anions, with the intensity of the signal corresponding to the concentration of the anion detected.

2. Cations -- Ammonium and Potassium Ions

Cations were analyzed in a similar manner as the anions except the eluent was nitric acid. The soluble cations were leached from the Nucleopore filter with a measured volume of 60 percent IPA and 40 percent water. An aliquot of this extract was injected via autosampler into an IC. Cations were separated by analytical column, and passed through a conductivity detector. The retention time on column provided identification of the cations, with intensity of the signal corresponding to the cation concentration.

IV. TEST RESULTS

A. Particle Size Distribution

Table 4 summarizes the results of the GE locomotive particle size distribution at Idle and Notch 8 for both fuels. Given are particulate matter (PM) mass emission rates in ten discrete particle size ranges, and a total particulate mass rate, which is the sum of all the stage fractions collected plus the backup filter.

As described in Section III.A of this report, duplicate tests were performed using the standard foil media and Nucleopore media in the MOUDI at each of the two operating conditions, and for each of the two test fuels. The data in Table 4 shows that the particle size distribution obtained with the foil plates and the Nucleopore media as an impaction plate yielded similar results, although the sum of the stage values (the total PM emission rate) was consistently higher when using the Nucleopore media compared to the foil plates. Table 4 also contains the PM rate for each test condition and fuel that is based on conventional PM sampling techniques using 90mm Pallflex T60A20 filter media. The value reported as "Total PM by 90mm" is the average of triplicate tests reported to the ARB as part of the main test program on this locomotive. Comparing the 90mm PM results to the PM totals by the MOUDI show that the Nucleopore media seemed to agree better than the foils, with the possible exception of the first Notch 8 run with the 0.3 percent sulfur fuel, where the total PM by MOUDI was almost twice as high as the 90 mm PM. Comparing the PM totals by MOUDI using foil plates are often compared against total PM measured with conventional sampling systems, and MOUDI total PM values are typically in the range of 60 to 90 percent of those measured by conventional 90mm filters. In this case, the Nucleopore filters used as impaction plates seemed to collect more mass at each stage compared to the foil plates, although the size distributions were similar. Due to the fact that the foil plates are the collection media typically used in MOUDI sampling, the following discussion of particle size is based on data using the foils.

The duplicate runs using the foil media were averaged, and the results are presented in Figure 5, in percentages of total PM mass as a function of particle size. At Idle, for both fuels, about 1 percent of the total PM mass was from particles larger than 2.5 Fm. At Notch 8, less than 1 percent of the total PM mass was from particles larger than 2.5 Fm, for both fuels. Figure 5 also shows that the 0.3 percent sulfur fuel had a larger percentage of smaller particles than the CARB diesel, at both Idle and Notch 8. Also, there was a larger fraction of smaller particles at Notch 8 than at Idle.

Figure 6 shows the particulate mass emission rate during Idle operation as a function of particle size, based on the aluminum foil collection plates. Both fuels exhibited a monomodal distribution, with the largest mass fraction at the 0.31 to 0.54 Fm size range. The PM mass emission rate was higher with the 0.3 percent sulfur fuel at all size ranges except at the 0.17 to 0.31Fm size range.

TABLE 4. GE LOCOMOTIVE ENGINE PARTICULATE EMISSION SIZE DISTRIBUTION SUMMARY

	0.3% Sulfur Nonroad Diesel				CARB Diesel			
Low Idle PM Emissions, g/hr								
PM Size Range, Fm	Foil Run 1	Foil Run 2	Nucleopore Run 1	Nucleopore Run 2	Foil Run 1	Foil Run 2	Nucleopore Run 1	Nucleopore Run 2
> 6.2	0.00	0.00	2.71	2.76	0.00	0.08	1.35	0.72
3.1 to 6.2	0.36	0.36	2.44	2.21	0.00	0.11	1.04	0.62
1.8 to 3.1	0.41	1.61	3.61	1.98	0.00	0.00	1.31	0.57
1.0 to 1.8	0.41	1.52	1.35	3.22	0.24	0.00	1.70	1.13
0.54 to 1.0	0.68	2.50	5.33	3.54	0.93	0.49	2.08	1.75
0.31 to 0.54	11.34	14.42	11.42	11.77	12.23	9.86	12.56	13.15
0.17 to 0.31	8.45	8.57	13.68	13.52	11.79	6.81	14.26	12.17
0.09 to 0.17	4.70	7.95	9.03	10.12	2.37	1.39	3.74	3.56
0.06 to 0.09	2.21	2.37	4.74	4.14	0.84	0.56	2.27	1.96
< 0.06	1.76	3.04	2.21	1.52	0.76	0.45	0.92	0.77
Total PM by MOUDI	**30.32**	**42.32**	**53.81**	**52.02**	**29.17**	**19.68**	**39.88**	**35.68**
Total PM by 90 mm [a]	**58**				**48**			
Notch 8 PM Emissions, g/hr								
> 6.2	6.43	2.77	47.76	25.12	3.07	0.00	0.00	24.71
3.1 to 6.2	0.00	0.00	95.51	19.53	0.00	0.00	21.54	12.35
1.8 to 3.1	2.57	0.00	78.06	17.67	2.30	0.00	15.38	27.02
1.0 to 1.8	0.00	2.77	110.21	32.56	0.00	1.58	23.08	27.79
0.54 to 1.0	3.86	3.70	138.68	60.46	4.60	0.00	19.23	23.93
0.31 to 0.54	69.44	92.47	175.41	143.25	76.67	76.78	86.92	101.14
0.17 to 0.31	39.86	58.25	177.25	85.58	45.24	40.37	66.15	66.40
0.09 to 0.17	115.74	115.58	195.62	156.28	69.00	44.33	76.15	54.04
0.06 to 0.09	102.88	114.66	117.55	141.39	68.24	51.45	79.23	57.90
< 0.06	61.73	54.55	59.70	48.37	30.67	29.29	30.00	36.29
Total PM by MOUDI	**396.07**	**441.99**	**1147.99**	**705.11**	**296.71**	**243.81**	**417.68**	**406.87**
Total PM by 90 mm [a]	**646**				**409**			

Notes: a - Total PM by 90 mm is the average of the triplicate runs made during regulated emissions testing of UP No. 9724, as measured using 90mm Pallflex T60A20 filters.

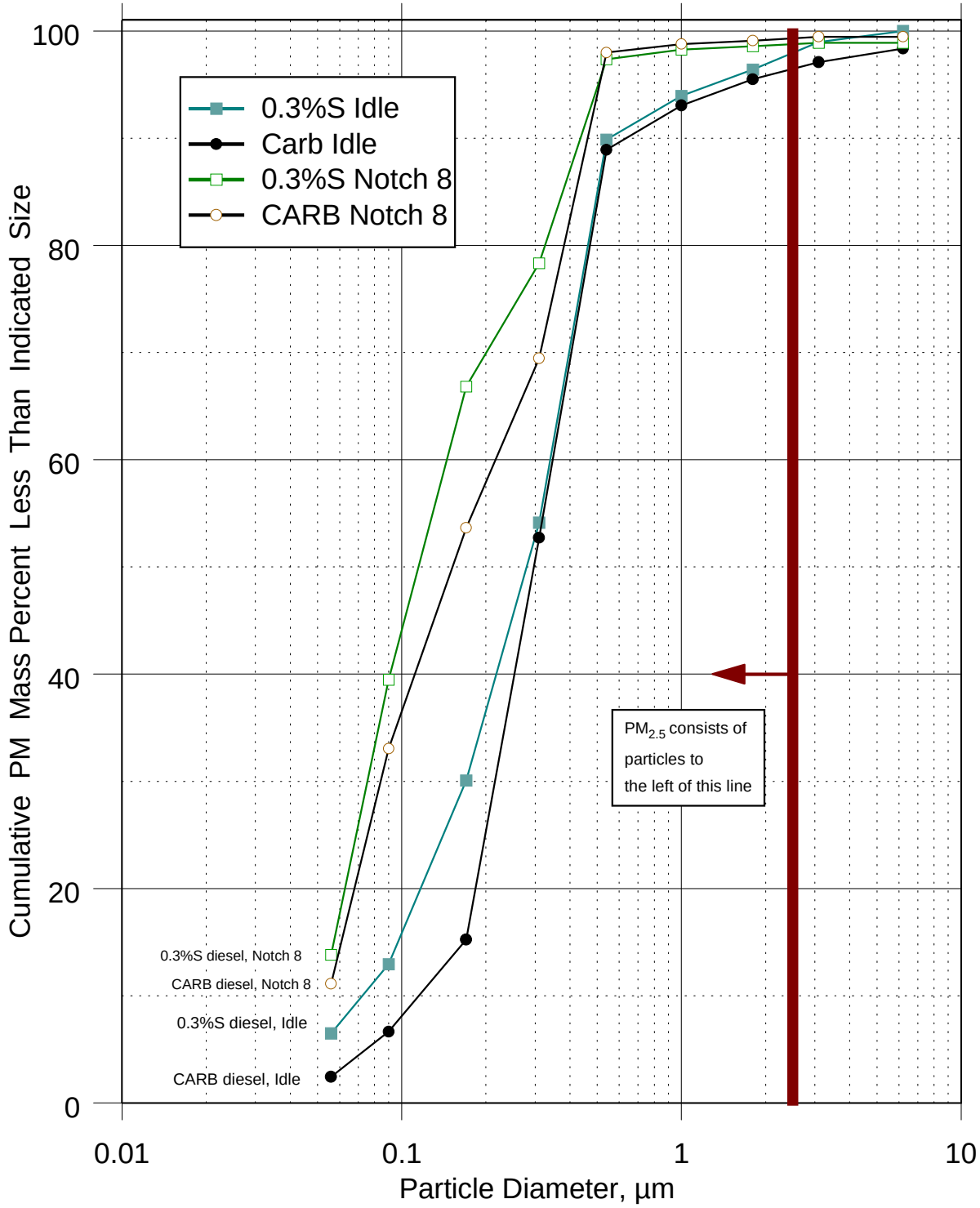

FIGURE 5. GE LOCOMOTIVE ENGINE PARTICLE SIZE DISTRIBUTION

Figure 7 shows the particulate mass emission rate during Notch 8 operation as a function of particle size, based on the aluminum foil collection plates. Comparing Idle to Notch 8, there is a noticeable shift in the particle size distribution toward smaller particles, and the total mass emission rate is about an order of magnitude higher. At Notch 8, less than 3 percent of the particulate mass emission was above 0.54 Fm for both fuels. An interesting characteristic of the size distribution at Notch 8 is that it was bimodal for both fuels, with one peak at 0.31 to 0.54 Fm size range, like that observed at Idle, but with a second peak around the 0.09 to 0.17Fm size range. It is at this peak in the smaller particle size range where the greatest difference in PM emissions between the two fuels was observed, with PM mass emissions with the 0.3 percent sulfur fuel nearly twice as high as the CARB diesel in the three size ranges below 0.17 Fm.

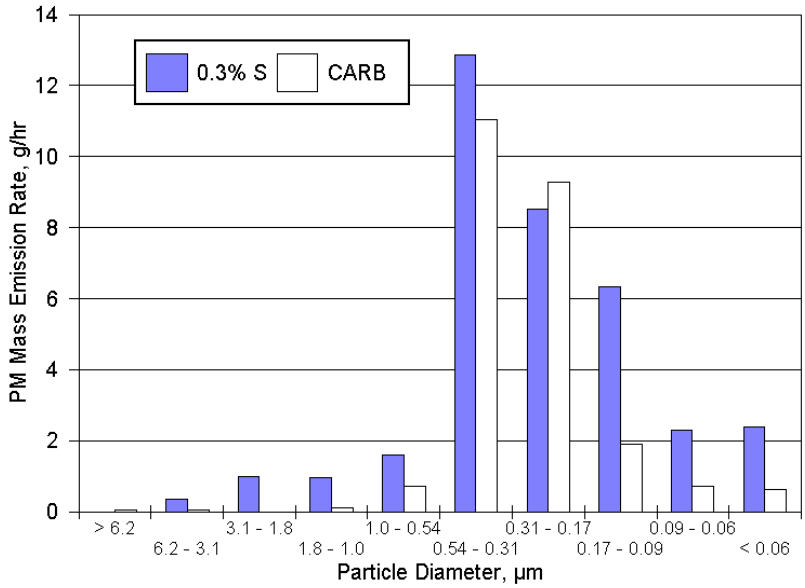

FIGURE 6. PARTICLE SIZE DISTRIBUTION AT IDLE

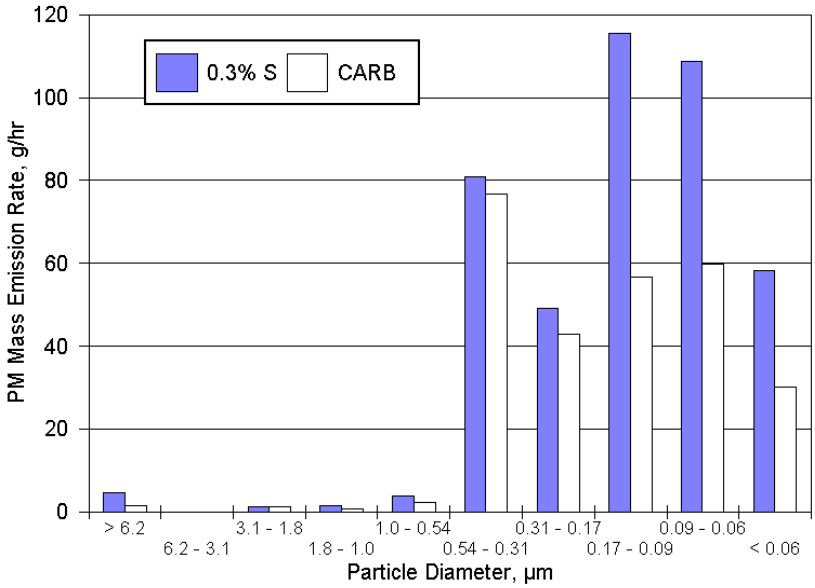

FIGURE 7. PARTICLE SIZE DISTRIBUTION AT NOTCH 8

B. Volatile Organic Fraction (VOF) of Particulate

Stages with mean diameter ranges of 0.54 Fm to 0.31 Fm, 0.31 Fm to 0.17 Fm, and 0.17 Fm to 0.09 Fm for Idle were analyzed by DFI/GC for VOF. At Notch 8, the same three stages used in Idle VOF analysis, plus the 0.09 Fm to 0.056 Fm stage, and the less than 0.056 Fm backup filter were examined. Particulate mass loadings for the other stages were too small to permit particulate characterization by VOF. The DFI/GC procedure provides a result based on the percentage of total PM that is VOF. In this case, the percentage of the PM was measured using the MOUDI foil plates. The percent VOF determined for each stage was applied to the average PM emission of the two runs made with the foil plates at each test condition. The VOF results are presented in Table 5, and in Figures 8 and 9.

TABLE 5. VOLATILE ORGANIC FRACTION (VOF) OF PARTICULATE

Engine Condition	Fuel	Average Total Particulate, g/hr	Size Range, Fm	% VOF	VOF, g/hr	% Unburned Oil of VOF	Unburned Oil, g/hr	Fuel-Derived VOF, g/hr
Idle	0.3% Sulfur	36	0.54-0.31	9.2	3.9	32	1.3	2.6
			0.31-0.17	7.3	3.1	21	0.7	2.4
			0.17-0.09	3.6	1.5	4	0.1	1.4
	CARB Diesel	24	0.54-0.31	4.9	1.0	40	0.4	0.6
			0.31-0.17	6.8	1.3	18	0.2	1.1
			0.17-0.09	4.0	0.8	6	0.04	0.8
Notch 8	0.3% Sulfur	419	0.54-0.31	6.3	27.7	15	4.2	23.5
			0.31-0.17	8.3	36.0	9	3.2	32.8
			0.17-0.09	10.5	45.9	15	6.9	39.0
			0.09-0.056	5.5	23.9	4	1.0	22.9
			<0.056	8.1	35.2	29	10.2	25.0
	CARB Diesel	270	0.54-0.31	7.0	17.1	22	3.8	13.3
			0.31-0.17	9.1	22.0	21	4.6	17.4
			0.17-0.09	7.4	17.9	25	4.5	13.4
			0.09-0.056	6.0	14.5	12	1.7	12.8
			<0.056	8.2	20.1	42	8.4	11.7

The data given in Table 5 shows that the VOF of the PM emissions from the GE engine is relatively low, and makes up only 5 to 10 percent of the total PM mass. Figures 8 and 9 show that the VOF is largely fuel-derived, at both Idle and Notch 8. The mass rate of unburned lubricating oil-derived VOF was generally similar for both fuels, especially during Notch 8 operation. At Idle, the lubricating oil derived VOF was higher with the 0.3 percent sulfur diesel fuel, compared to the CARB diesel, with notable increases observed at the two larger size ranges analyzed. At Notch 8, the largest contribution to the VOF from unburned lubricating oil was at the smallest size range analyzed, which was less than 0.056 Fm.

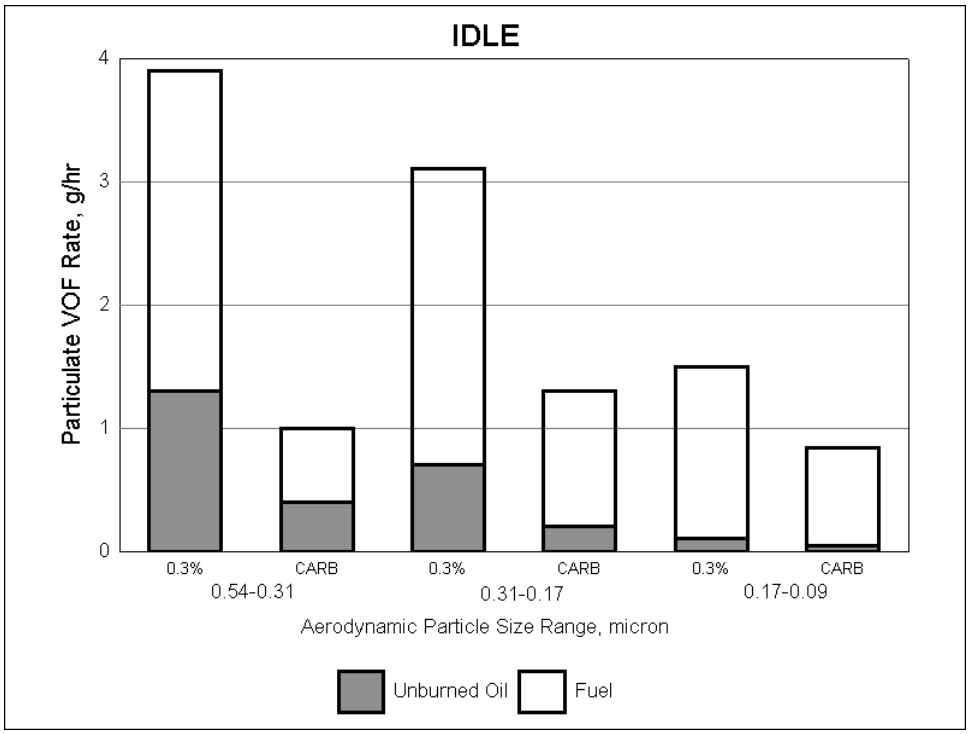

FIGURE 8. VOF AT IDLE

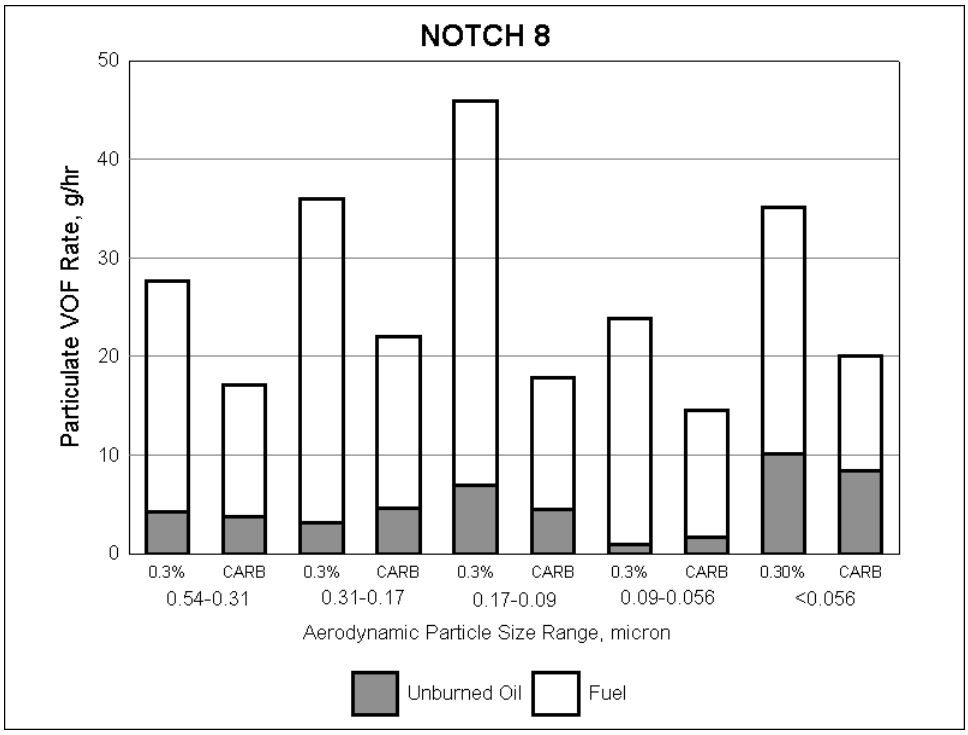

FIGURE 9. VOF AT NOTCH 8

C. Elemental Analysis

MOUDI stages using Nucleopore filters and with particle sizes of 0.54 Fm to 0.31 Fm, 0.31 Fm to 0.17 Fm, and 0.17 Fm to 0.09 Fm for Idle were analyzed by ICP/MS for selected elements. At Notch 8, the same stages, plus the 0.09 Fm to 0.056 Fm stage, and the less than 0.056 Fm backup filter were examined. Particulate mass loadings for the other stages were too low to permit particle characterization. A total of 44 elements were analyzed for, but most were below their detection limit.

Appendix A gives the tabulated results of the elemental analysis on selected MOUDI stages. Only four elements (barium, magnesium, potassium, and sulfur) were above the detection limit for the stages analyzed, and only sulfur was found repeatedly. Several elements were found at trace levels, defined as being present above the detection limit, but at a concentration less than three times the detection limit.

D. Anion and Cation Emissions

MOUDI stages with size ranges of 0.54 Fm to 0.31 Fm, 0.31 Fm to 0.17 Fm, and 0.17 Fm to 0.09 Fm for Idle were analyzed by IC for anion and cation emissions. At Notch 8, the same three stages, plus the 0.09 Fm to 0.056 Fm range were examined. Particulate mass loadings for the other stages were too small to permit analysis. The anions included chloride, nitrate, and sulfate ions; and the cations included ammonium and potassium ions. Analyses for bromine were also conducted, but no bromine was found in any of the samples. Table 6 presents the results for the anions and cations by particle size distribution.

TABLE 6. EXHAUST ANION AND CATION MASS EMISSIONS

Engine Condition	Fuel	Particle Size Range, Fm	Chloride Ion, mg/hr	Nitrate Ion, mg/hr	Dry Sulfate Ion, mg/hr	Ammonium Ion, mg/hr	Potassium Ion, mg/hr
Idle	0.3% Sulfur	0.54 - 0.31	1.8	6.8	70	91	34
		0.31 - 0.17	ND[1]	3.9	110	130	ND
		0.17 - 0.09	ND	9.8	120	170	120
	CARB diesel	0.54 - 0.31	15	3.6	36	120	ND
		0.31 - 0.17	6.6	2.9	26	33	96
		0.17 - 0.09	ND	12	17	ND	160
Notch 8	0.3% Sulfur	0.54 - 0.31	43	110	4,600	2,700	1,500
		0.31 - 0.17	17	93	5,100	3,800	2,700
		0.17 - 0.09	130	46	31,000	9,500	1,700
		0.09 - 0.056	ND	140	33,000	11,000	2,300
	CARB Diesel	0.54 - 0.31	230	170	1,500	580	69
		0.31 - 0.17	29	55	1,200	570	1,800
		0.17 - 0.09	90	100	2,900	2,500	ND
		0.09 - 0.056	230	88	3,500	3,500	ND

Notes: 1 - ND-none detected; below detection limit.

1. Chloride Ion Mass Emission Rates

Figures 10 and 11 show the chloride ion mass emission rates by particle size distribution for the two engine conditions. The chloride ion mass emission rates using CARB fuel were higher than for the 0.3 percent sulfur nonroad diesel fuel at both Idle and Notch 8.

Chloride ion mass emission rates at Notch 8 were the lowest for the 0.31 Fm to 0.17 Fm particle size range. At the 0.09 Fm to 0.056 Fm range with the 0.3 percent sulfur fuel, no chloride ion was detected. The chloride ion mass emissions were also greater for all size ranges with the CARB fuel, except for the 0.17 Fm to 0.09 Fm range at Notch 8.

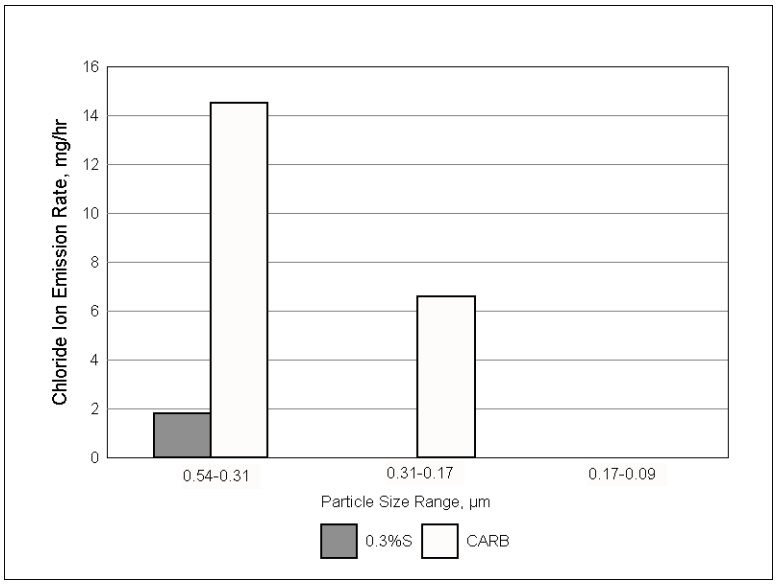

FIGURE 10. CHLORIDE ION MASS EMISSION RATE AT IDLE

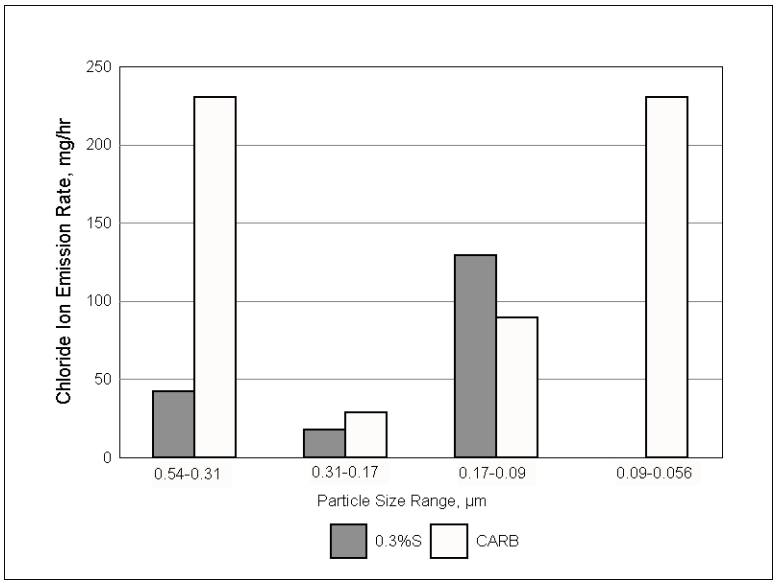

FIGURE 11. CHLORIDE ION MASS EMISSION RATE AT NOTCH 8

2. Nitrate Ion Mass Emission Rates

Figures 12 and 13 show the various nitrate ion mass emission rates by particle size distribution for the two engine conditions. Nitrate ion mass emission rates at Notch 8 were at least one order of magnitude greater than at Idle for both fuels. The differences in nitrate ion mass emission rates between the two fuels for all size ranges did not appear to be related to the nitrogen content in the fuel.

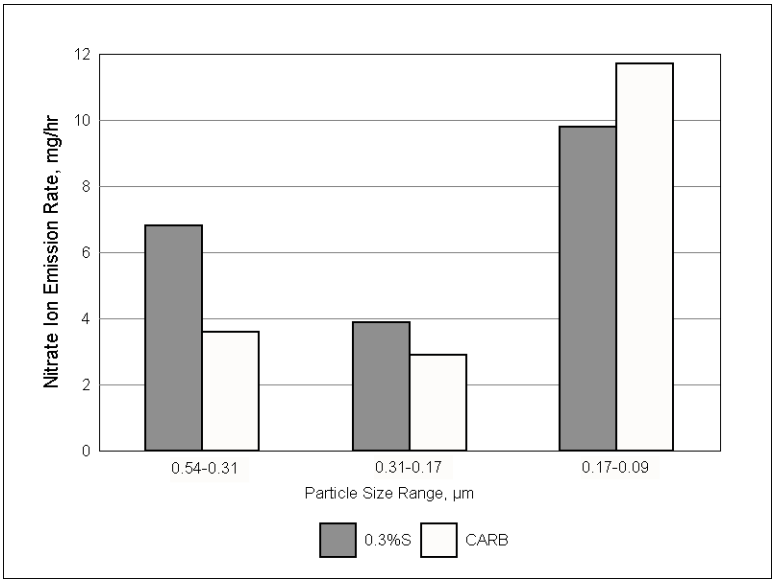

FIGURE 12. NITRATE ION MASS EMISSION RATE AT IDLE

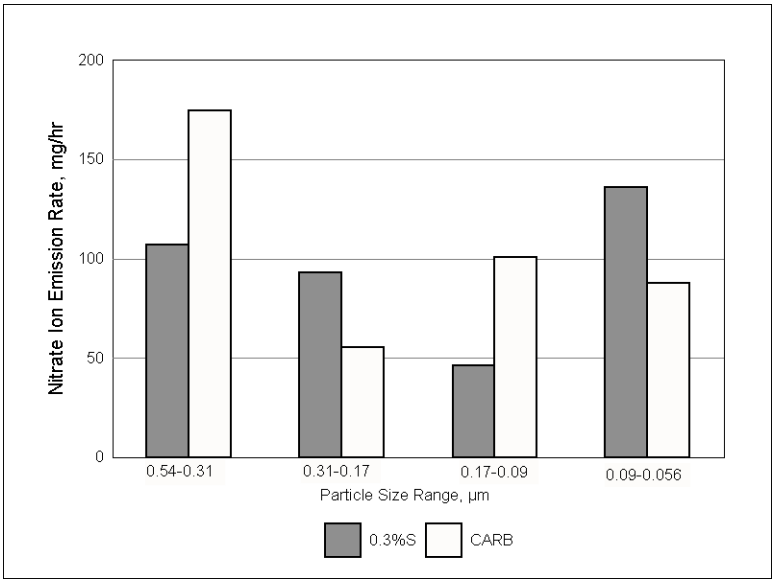

FIGURE 13. NITRATE ION MASS EMISSION RATE AT NOTCH 8

3. Sulfate Ion Mass Emission Rates

To isolate the specific effect of fuel sulfur content on change in particulate emissions, sulfate analyses were performed. Sulfate emissions are summarized in Table 7. Sulfate is reported here as "wet" sulfate, because sulfate is generally composed of sulfuric acid, H_2SO_4, with associated bound water. The hydration state of the sulfuric acid is very sensitive to the relative humidity in the PM filter weighing chamber. At 50 percent relative humidity in the weighing chamber, the hydration of one gram of sulfuric acid results in 1.3 grams of water per gram of H_2SO_4. This hydration means that the fraction of the total particulate mass due to the sulfate is 2.3 times the mass of the "dry" sulfate alone, because of the associated water.

Results given in Table 7 show that at Idle, sulfates contribute only a small percentage of the total PM, independent of the fuel. At Notch 8, however, sulfate made up over half of the total PM at the size range 0.09 to 0.056 Fm while using the 0.3 percent sulfur nonroad diesel fuel. For CARB diesel, which had a sulfur content of 50 ppm, sulfates contributed only 14 percent of the total PM at the same size range.

TABLE 7. SULFATE MASS EMISSION SUMMARY

Engine Condition	Fuel	Particle Size Range, Fm	Total[a] PM, mg/hr	"Dry" Sulfate, mg/hr	"Wet" Sulfate[b], mg/hr	"Wet" Sulfate, % of total PM
Idle	0.3% Sulfur	0.54 - 0.31	12,000	70	160	1
		0.31 - 0.17	14,000	110	260	2
		0.17 - 0.09	10,000	120	280	3
	CARB diesel	0.54 - 0.31	13,000	36	82	0.6
		0.31 - 0.17	12,000	26	59	0.5
		0.17 - 0.09	3,600	17	38	1
Notch 8	0.3% Sulfur	0.54 - 0.31	140,000	4,60	11,000	7
		0.31 - 0.17	86,000	5,100	12,000	14
		0.17 - 0.09	160,000	31,000	71,000	45
		0.09 - 0.056	140,000	33,000	75,000	53
	CARB Diesel	0.54 - 0.31	100,000	1,500	3,400	3
		0.31 - 0.17	66,000	1,200	2,600	4
		0.17 - 0.09	54,000	2,900	6,800	13
		0.09 - 0.056	58,000	3,500	8,000	14

Notes: a - Total PM for each MOUDI stage using Nucleopore filter media.
b - "wet" sulfate equals 2.3× "dry" sulfate.

Figures 14 and 15 show the sulfate mass emission rates by particle size distribution for the two engine conditions. The sulfate ion mass emission rates at Idle increased with decreasing particle size for the 0.3 percent sulfur fuel, and decreased with decreasing particle size with the CARB diesel.

Sulfate ion mass emission rates at Notch 8 increased with decreasing particle size for both fuels. The mass emission rates for sulfate ion with the 0.3 percent sulfur fuel were almost a factor of five times greater than with the CARB diesel.

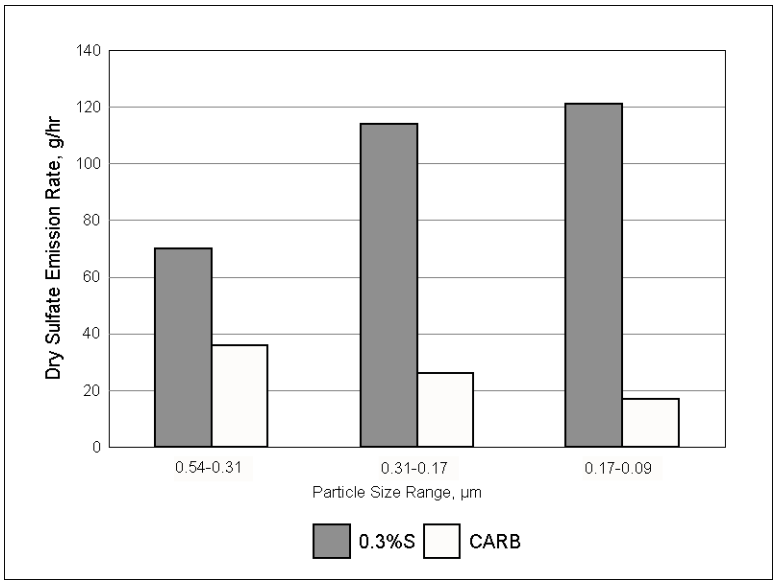

FIGURE 14. DRY SULFATE ION MASS EMISSION RATE AT IDLE

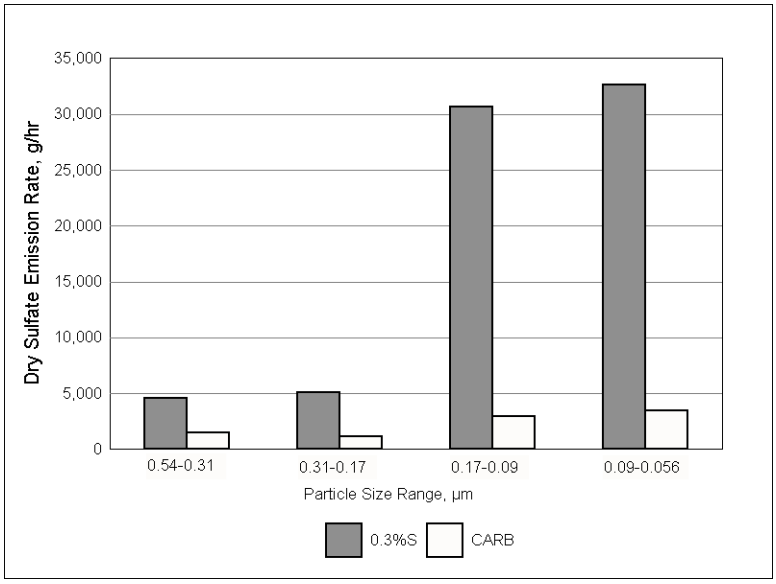

FIGURE 15. DRY SULFATE ION MASS EMISSION RATE AT NOTCH 8

4. Ammonium Emissions

Figures 16 and 17 show ammonium ion mass emission rates by particle size distribution for the two engine conditions. Ammonium mass emission rates at Idle increased with smaller particle size for the 0.3 percent sulfur fuel, and decreased with smaller particle size range with the CARB diesel. Overall, ammonium mass emissions were greater for the 0.3 percent sulfur fuel, except for the 0.54 to 0.31 Fm size range for CARB diesel. Ammonium ion mass emissions at Notch 8 increased with decreasing particle size for both fuels.

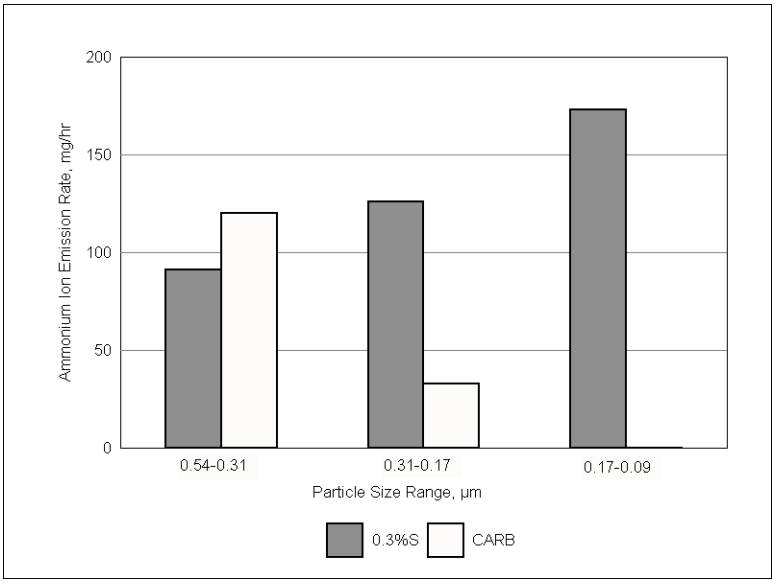

FIGURE 16. AMMONIUM ION MASS EMISSION RATE AT IDLE

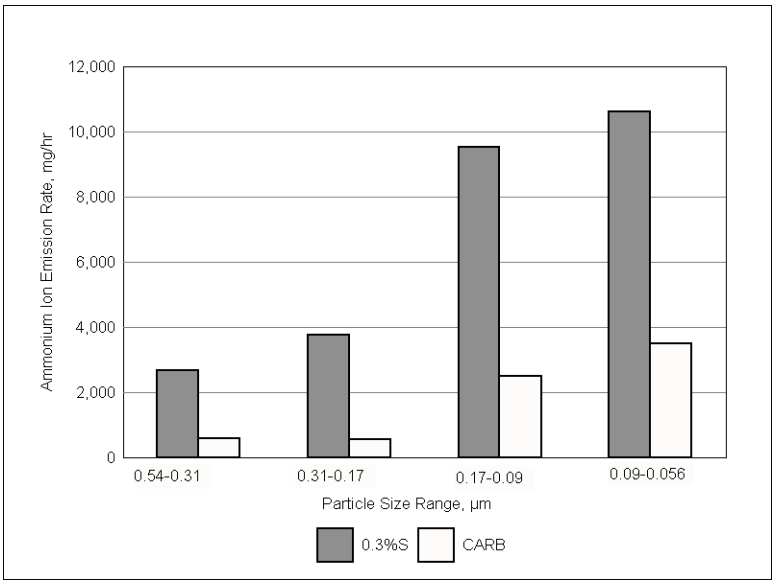

FIGURE 17. AMMONIUM ION MASS EMISSION RATE AT NOTCH 8

5. Potassium Ion Mass Emission Rates

Figures 18 and 19 show potassium ion mass emission rates by particle size distribution for the two engine conditions. No trends were noted in the potassium ion mass emission rates for any particle size range with either fuel or engine operating condition.

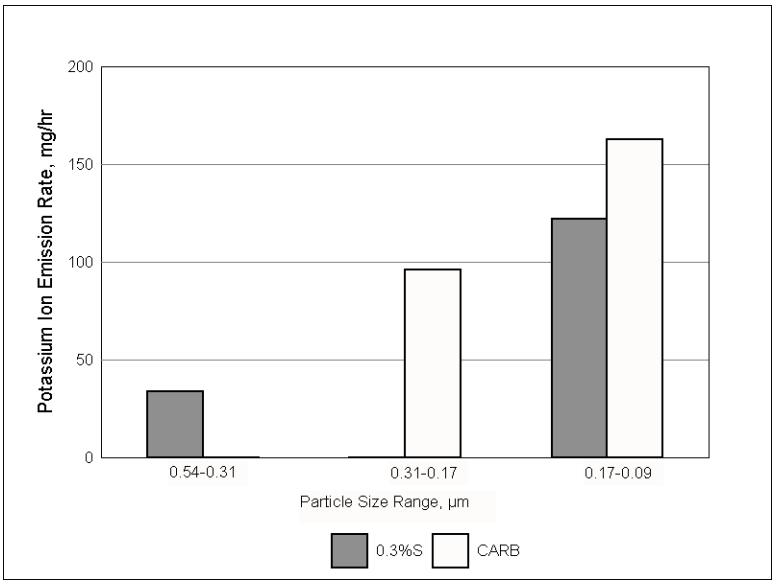

FIGURE 18. POTASSIUM ION MASS EMISSION RATE AT IDLE

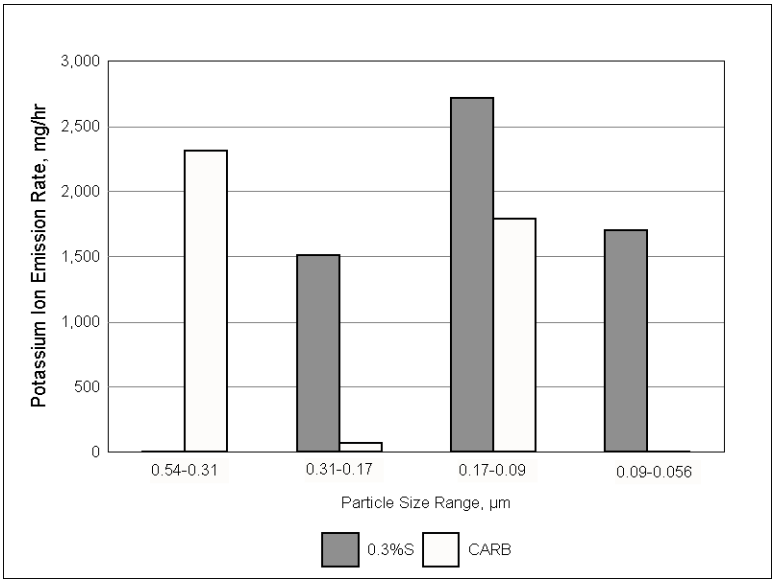

FIGURE 19. POTASSIUM ION MASS EMISSION RATE AT NOTCH 8

V. SUMMARY

Testing was performed to provide the ARB with data on the characterization of total particulate for various particle size fractions from a 4,400 hp GE locomotive. Two fuels were used in this study, a 0.3 percent sulfur nonroad diesel, and a CARB diesel. Sampling for particle sizing was conducted at two different operating conditions, Idle and Notch 8. Particulate characterization by particle size included volatile organic content, elemental analysis, and anion and cation levels.

Less than one percent of the particles were larger than 2.5 Fm for both fuels. The particle size distribution at Idle was monomodal, and at Notch 8 it was bimodal.

Total particulate mass emission was higher with the higher sulfur fuel for both operating conditions. Particulate emissions by particle size were similar for both fuels, down to a particle size range between 0.31 Fm to 0.17 Fm. At the smaller size ranges (0.17 Fm to 0.09 Fm, 0.09 Fm to 0.056 Fm, and less than 0.056 Fm), the CARB fuel produced lower masses of particles. This difference was also reflected in the fuel-derived VOF and the sulfate contribution to the total particulate mass. The sulfate mass emission rate was proportional to the fuel sulfur level.

Only five of 44 chemical elements were noted above the detection limit for the particle size ranges analyzed. The metal elements were mostly attributed to engine wear metals, and sulfur was associated with the fuel and lubricating oil. Except for sulfur, the metal elements were only a small fraction of the total particulate. At Idle and Notch 8, most of the detected elements were found in the larger particle size ranges (0.54 Fm to 0.31 Fm, 0.31 Fm to 0.17 Fm and 0.17 Fm to 0.09 Fm).

When operating at Idle, the 0.3 percent sulfur fuel showed a decrease in the VOF with decreasing particle size, while the CARB diesel yielded the highest VOF mass rate in the intermediate 0.31 Fm to 0.17 Fm size range. The percent of VOF attributed to unburned lubricating oil decreased with smaller particle sizes for both fuels at Idle, with the largest contribution occurring in the 0.54 Fm to 0.31 Fm size range. No consistent trends were noted for the Notch 8 condition.

For Notch 8, the average total particulate mass rate and the VOF were larger with the 0.3 percent sulfur fuel than with CARB diesel. Unburned lubricating oil derived VOF contributed about 57 percent of the VOF for the 0.3 percent sulfur fuel and about 64 percent for CARB diesel. At Notch 8, the unburned lubricating oil derived VOF was similar for both fuels, with the highest levels found in particles less than 0.056 Fm. The higher VOF levels with the 0.3 percent sulfur fuel were mostly fuel-derived VOF.

For the cations and anions, sulfate was highest with the higher sulfur fuel. Chloride, nitrate, and potassium ions were found to be only a small fraction of the total particulate. The mass emission rates for each ion were higher at Notch 8 than at Idle.

APPENDIX A

ELEMENTAL ANALYSIS RESULTS

Element Name	Element Symbol	Detection Limit (µg/filter)	Filter No.=	9226.6-895	9227.6-896	9228.6-897	9244.6-913	9245.6-914	9246.6-915	9247.6-916	9266.1-845	9352.6-931	9353.6-932	9354.6-933	9370.6-976	9371.6-977	9372.6-978	9373.6-979	9266.1-845	Blank	Blank
			Fuel =	HS	HS	HS	HS	HS	HS	HS	HS	CARB	CARB	CARB	CARB	CARB	CARB	CARB	CARB	47mm	37mm
			Test Run # =	R2	R2	R2	R6	R6	R6	R6	R6	R10	R10	R10	R14	R14	R14	R14	R14	Nucleopore	Pallflex
			PM Size Range, µm	0.54 - 0.31	0.31 - 0.17	0.17 - 0.09	0.54 - 0.31	0.31 - 0.17	0.17 - 0.09	0.09 - 0.06	<0.06 Pallflex	0.54 - 0.31	0.31 - 0.17	0.31 - 0.17	0.54 - 0.31	0.31 - 0.17	0.17 - 0.09	0.09 - 0.06	<0.06 Pallflex		
			Test Condition	Idle	Idle	Idle	Notch 8	Notch 8	Notch 8	Notch 8	Notch 8	Idle	Idle	Idle	Notch 8	Notch 8	Notch 8	Notch 8	Notch 8		
			Sample Results, µg/filter																		
Aluminum	Al	30		36.6	nd	nd	nd	nd	nd	nd	726	nd	nd	70.6	nd	33.5	nd	nd	625	0	649
Antimony	Sb	0.1		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0	0
Arsenic	As	0.1		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0	0
Barium	Ba	5		10.2	11.6	nd	nd	nd	nd	nd	326	nd	nd	17	nd	nd	nd	nd	275	0	264
Beryllium	Be	0.05		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0	0
Bismuth	Bi	0.1		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0	0
Boron	B	75		nd	nd	nd	nd	nd	nd	nd	919	nd	nd	nd	nd	nd	nd	nd	790	0	892
Cadmium	Cd	0.05		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0	0
Calcium	Ca	125		nd	134	nd	130	128	126	129	651	nd	nd	nd	nd	130	131	nd	571	129	632
Chromium	Cr	0.1		0.762	0.423	0.451	0.408	0.476	0.384	0.351	0.147	0.349	0.402	0.340	0.428	0.410	0.378	0.358	nd	0.52	0
Cobalt	Co	0.1		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0	0
Copper	Cu	0.1		nd	0.107	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0	0
Gallium	Ga	0.05		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0	0
Gold	Au	0.05		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0	0
Indium	In	0.05		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0	0
Iron	Fe	1		2.34	nd	1.1	nd	nd	nd	nd	1.44	nd	nd	nd	nd	nd	nd	nd	1.25	1.04	1.16
Lanthanum	La	0.1		0.152	0.114	0.385	0.339	0.134	nd	nd	0.207	0.145	nd	nd	nd	nd	0.146	nd	nd	0.126	0.204
Lead	Pb	0.05		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0	0
Lithium	Li	0.1		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0	0
Magnesium	Mg	0.5		nd	nd	nd	nd	nd	nd	1.65	0.702	nd	nd	nd	nd	nd	nd	nd	1.02	0	1.09
Manganese	Mn	1		2.17	nd	nd	1.92	1.03	nd	nd	nd	nd	1.79	nd	1.24	1.01	2.16	nd	nd	0	0
Mercury	Hg	0.1		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0	0
Molybdenum	Mo	0.1		nd	nd	nd	nd	0.153	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0	0
Nickle	Ni	0.1		0.265	nd	0.173	0.266	0.135	nd	nd	nd	nd	nd	0.239	nd	nd	nd	nd	nd	0	0
Palladium	Pd	0.05		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0	0
Phosphorus	P	0.25		nd	0.275	nd	nd	0.266	nd	nd	0.255	nd	nd	nd	nd	nd	nd	nd	0.416	0	0.266
Potassium	K	30		nd	nd	53.1	nd	47	nd	nd	1870	nd	nd	nd	nd	90.8	nd	75.9	1650	0	1630
Rubidium	Ru	0.05		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0	0
Selenium	Se	0.15		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0	0
Silicon	Si	50		85.3	85.6	55.5	60.5	77.1	55	nd	8840	nd	nd	129	nd	60.7	nd	nd	7920	0	8170
Silver	Ag	0.1		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0	0
Sodium	Na	2		2.78	nd	2.12	nd	2.77	nd	2.16	57.9	nd	3.41	nd	nd	nd	nd	nd	94.3	0	108
Strontium	Sr	2.5		nd	nd	nd	nd	nd	nd	nd	13.8	nd	nd	nd	nd	nd	nd	nd	12.1	4.46	11.4
Sulfur	S	1		3.11	2.84	3.95	1.63	3.65	9.07	9.65	5.19	2.2	2.38	1.08	1.57	1.78	2.56	2.38	2.32	0	2.27
Thallium	Tl	0.1		0.23	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0	0
Thorium	Th	0.1		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0	0
Tin	Sn	0.1		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0	0
Titanium	Ti	0.5		nd	nd	0.505	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0	0
Tungsten	W	0.15		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0	0
Uranium	U	0.05		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0	0
Vanadium	V	0.05		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0	0
Yttirum	Y	0.1		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0	0
Zinc	Zn	2.5		3.74	6.96	nd	3.21	nd	nd	nd	378	nd	nd	3.45	nd	nd	nd	nd	367	0	421
Zireonium	Zr	0.1		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0	0
Bromide	Br-	5		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0	0
Chloride	Cl	5		nd	nd	nd	13.5	5.2	nd	nd	nd	nd	8	8.9	nd	nd	nd	nd	nd	0	0

Element Name	Element Symbol	Filter No.=	9226.6-895	9227.6-896	9228.6-897	9244.6-913	9245.6-914	9246.6-915	9247.6-916	9266.1-845	9352.6-931	9353.6-932	9354.6-933	9370.6-976	9371.6-977	9372.6-978	9373.6-979	9266.1-845
		Fuel =	HS	HS	HS	HS	HS	HS	HS	HS	CARB	CARB	CARB	CARB	CARB	CARB	CARB	CARB
		Test Run # =	R2	R2	R2	R6	R6	R6	R6	R6	R10	R10	R10	R14	R14	R14	R14	R14
		PM Size Range, µm	0.54 - 0.31	0.31 - 0.17	0.17 - 0.09	0.54 - 0.31	0.31 - 0.17	0.17 - 0.09	0.09 - 0.06	<0.06 Pallflex	0.54 - 0.31	0.31 - 0.17	0.31 - 0.17	0.54 - 0.31	0.31 - 0.17	0.17 - 0.09	0.09 - 0.06	<0.06 Pallflex
		Test Condition	Idle	Idle	Idle	Notch 8	Notch 8	Notch 8	Notch 8	Notch 8	Idle	Idle	Idle	Notch 8	Notch 8	Notch 8	Notch 8	Notch 8
Aluminum	Al	Mass Emission Rate, µg/hr	T							T	T	T	T	T	T	T	T	
Antimony	Sb																	
Arsenic	As																	
Barium	Ba		T	T						T			655					T
Beryllium	Be																	
Bismuth	Bi																	
Boron	B																	
Cadmium	Cd																	
Calcium	Ca																	
Chromium	Cr		T							T								
Cobalt	Co																	
Copper	Cu			T														
Gallium	Ga																	
Gold	Au																	
Indium	In																	
Iron	Fe		T															
Lanthanum	La				T	T												
Lead	Pb																	
Lithium	Li																	
Magnesium	Mg								1515									
Manganese	Mn		T			T	T					T		T	T	T		
Mercury	Hg																	
Molybdenum	Mo						T											
Nickle	Ni		T		T	T	T						T					
Palladium	Pd																	
Phosphorus	P			T			T											
Potassium	K				T		T			T					69842		T	
Rubidium	Ru																	
Selenium	Se																	
Silicon	Si		T	T	T	T	T	T		T			T		T			
Silver	Ag																	
Sodium	Na		T		T		T		T			T						
Strontium	Sr																	
Sulfur	S		140	T	178	T	3352	8330	8862	T	T	T	T	T	T	T	T	
Thallium	Tl		T															
Thorium	Th																	
Tin	Sn																	
Titanium	Ti				T													
Tungsten	W																	
Uranium	U																	
Vanadium	V																	
Yttirum	Y																	
Zinc	Zn		T	T		T							T					
Zireonium	Zr																	
Bromide	Br-																	
Chloride	Cl					T	T					T	T					